SCIENTIFIC AGRICULTURE

Vol. XIX | AUGUST, 1939 | No. 12

PASTURE STUDIES XV[1]

THE INTRA-SEASONAL CHANGES IN THE NUTRITIVE VALUE OF PASTURE HERBAGE

E. W. Crampton[2] and R. P. Forshaw[3]

Macdonald College, Que.

[Received for publication June 21, 1939]

INTRODUCTION

On account of the importance of pasture in Eastern Canada, investi gational work to determine the factors affecting pastures has been in progress since 1931 under the Macdonald College Pasture Committee. As a part of the nutritional phase of the project the effects of fertilization upon the nutritive value of mixed pasture herbage and pure species have been studied. Marked improvement in nutritive value of herbage from fertilized plots over that from similar untreated plots was unexplainable on the basis of increase in protein content alone (6). Furthermore, changes in nutritive value from season to season were unsatisfactorily explained on the basis of the ordinarily reported chemical analyses (1). A continuance of this work has led to an investigation of the intra-seasonal changes in nutritive value of a mixed Kentucky blue grass, red top, wild white clover pasture.

REVIEW OF LITERATURE

Woodman, Blunt and Stewart (14) working with medium pasturage on a light sandy soil at the School of Agriculture, Cambridge University, England, found a slight but progressive diminution in feeding value, as measured by chemical analyses and digestibility coefficients, during the mid-season, the grass cut in the droughty period having the poorest value. In subsequent periods, with ample rainfall, the grass showed a steady improvement until it was but little inferior to that cut at the early part of the season. A later paper (15) confirms the finding that there need be no serious falling off in nutritive value of closely grazed pasturage, when the conditions in respect of soils, herbage and weather combine to enable the pasture to display continuous active growth. In such cases the cell wall would be prevented from undergoing extensive lignification and the crude fibre would be composed of the simple form of cellulose unmixed with any significant amount of the less digestible lingo-cellulose.

Woodman, Norman and Bee (17) found no indication of a diminution in digestibility of fibre as a result of increasing the intervals between clippings from a week to a fortnight. They further report (18) that, while cutting at 3-week intervals led to a slight lowering of the percentage protein and an increase in the percentage of crude fibre and nitrogen-free extract,

[1] Macdonald College Journal Series No. 128.

[2] Associate Professor of Animal Nutrition, Faculty of Agriculture, McGill University, Macdonald College, Quebec, Canada.

[3] Graduate assistant in Animal Nutrition.

the grass still maintained the non-lignified, highly digestible character possessed by that cut at shorter intervals.

Woodman, Norman and French (19) report that if pastures are well grazed in the fall there is little or no danger of the chemical composition of the herbage decreasing during the first month. Under a system of monthly cuttings grass was found to reach a stage of maturity at which lignification had set in with consequent decline in digestibility. Woodman and Oostheuizen (20) found that despite its leafy characteristic winter grass had undergone considerable lignification. The improved digestibility of fibre and other constituents of February grass pointed to a lessened degree of lignification.

Hall and Russel (7) of the Rothamstead Station noted that the leafy habit of growth characterized the fatting fields of Romney while the stemmy habit was characteristic of the poor fields. Fagan and Jones (5) of Aberystwyth state that a knowledge of the relative proportions of leaf to stem will prove a fair guide to nutritive value of a pasture at any given period of the year. These workers found that the proportion of leaf to stem was highest in June and lowest in July and that the composition of the leaf portion was far superior to that of the stem in all cases, the difference being least in early spring and early autumn. Woodman, Evans and Norman (16) attributed the superiority in nutritive value of pasture herbage over prebudding lucerne to differences in digestibility of the fibre, which in lucerne begins to show signs of lignification at an early stage. As protein and nitrogen-free extract showed no corresponding falling off it is suggested that lignification takes place first largely in the stems and may be related to the growth habit of the plant. Woodman, Blunt and Stewart (14) report among other causes of the seasonal changes in digestibility that too strenuous cutting tends to reduce the percent leaf in the cut.

Morris, Wright and Fowler (10) of the Hannah Dairy Research Institute, Kirkhill, Ayr, Scotland, report that the proteins of spring grass are markedly superior to those of autumn grass for milk production.

Chemical analyses in conjunction with digestibility coefficients have been taken as a measure of nutritive value. But little emphasis has been laid on the effect of changes in chemical composition and digestibility upon nutritive value as measured by live weight increase or production per unit of feed eaten. Cameron (1) found that observed differences in nutritive value from season to season under conditions prevailing in Eastern Canada could not be satisfactorily explained on the basis of the ordinarily reported chemical analyses. Crampton and Maynard (4) have pointed out the limitations of the present system of analyses as an index to probable nutritive value. Maynard (9) states that the separation of the carbohydrate fraction into crude fibre and nitrogen-free extract has a variable significance as regards nutritive value.

Norman (11) has shown the variability of crude fibre as isolated by the official procedure, and Williams and Olmstead (13) have pointed out the inadequacy of the Weende method of determining crude fibre as an index of the amount of indigestible residue present. Mangold (8) has shown that the crude fibre fraction may or may not be well digested. Data summarized by Crampton (2) shows that in 67% of the reported studies crude fibre in pasture herbage had as high or higher digestibility than nitrogen-free extract.

Perusal of the literature reveals that the greater proportion of the work dealing with the nutritive value of young pasture herbage has been done under conditions quite different to those encountered in Eastern Canada. As conditions in respect of herbage, soil, rainfall and temperature would seem to be factors of such great importance in determining changes in nutritive value and as these conditions in Eastern Canada might combine to give different findings than those reported, the repetition of this work seemed warranted. In view of the unsatisfactory nature of the present feeding-stuffs analyses the partition proposed by Crampton and Maynard (4) was used in addition to the regular feedingstuffs analyses in an attempt to more clearly explain differences that might be observed.

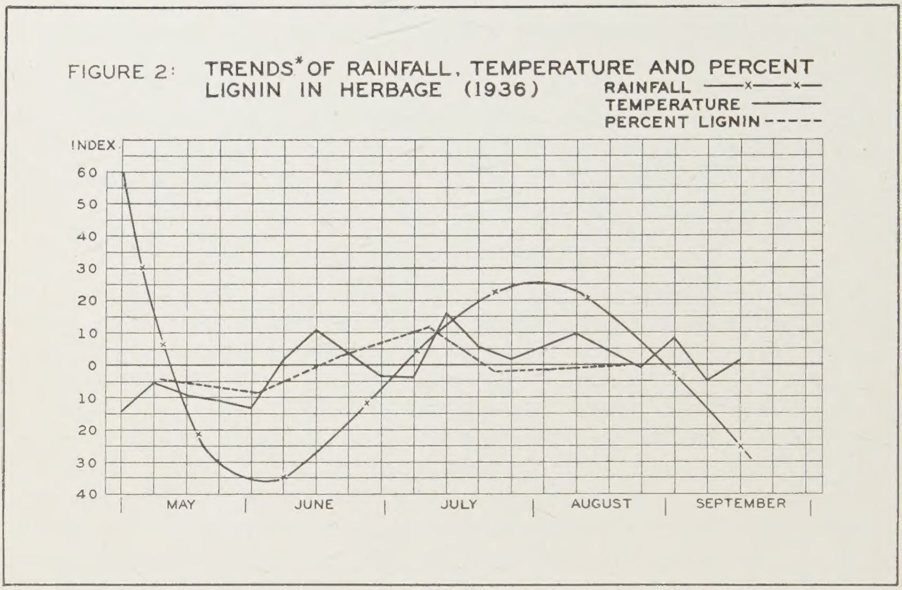
MATERIAL AND METHODS

Herbage clippings from a mixed Kentucky blue grass, red top, wild white clover lawn cut at regular short intervals (approximately 10 days) were fed as sole diets. The area from which the clippings were taken had received no fertilizer since being placed in sod (29 years), but all mowings had been returned. While the intervals between clippings were short (average 10.0 ± 3.40 days) the herbage in certain clippings taken during June and July was rapidly approaching maturity.

The grass was cut by tractor-drawn lawn mowers and caught in specially designed sheet metal hoppers (see photograph). The gass was spread thinly on burlap sheets until removal to the drying room. Drying, which was carried out in a forced draught, hot-air dryer, required from 2 to 2½ hours. The dried grass was ground in a hammer mill to pass a 15/32 inch screen and stored in burlap bags. Seven clippings representing herbage grown at various intervals throughout the season were chosen for this study. The analyses of the feeds used are given in Appendix Table I.

FIGURE 1.—Grass collecting equipment used at Macdonald College.

The seasonal trends of rainfall, temperature and percentage lignin in the herbage are given in Figure 2.



*Mean values: Weekly = ·71 inches; Daily mean temperature = 71·3°F.; Lignin = 11·54%

Animals Used and Allotment

Seventy newly weaned rabbits of approximately 7 weeks of age and weighing from 1200 to 1400 grams each were divided into two groups (A and B) of 35. The animals of each group were allotted at random to 7 lots of 5, the rabbits in each lot being fed grass from a separate clipping.

Data concerning dates of trials and length of preliminary and test periods are given in Table 1.

Table 1.—Growth trial

Group	Preliminary period		Test period	
	Date started	Days	Date started	Days
Group A	Nov. 13, 1936	7	Nov. 20, 1936	28
Group B	Mar. 8, 1937	7	Mar. 15, 1937	28

Feeding Equipment and Practice

The feeding equipment and practice was that in use in the laboratory and has previously been described (3). Rabbits were individually penned throughout the trial and weekly live weight gain and feed consumption were recorded for each animal. Thirty-six individual cages fitted for the collection of faeces and urine separately were used during the digestibility trial.

Growth Trial Results

The average initial weight, dry matter consumption, observed live weight gain and live weight gain adjusted for differences in initial weight and dry matter consumption are given in Table. 2.

TABLE 2.—INITIAL WEIGHT, DRY MATTER CONSUMPTION AND LIVE WEIGHT GAIN DATA

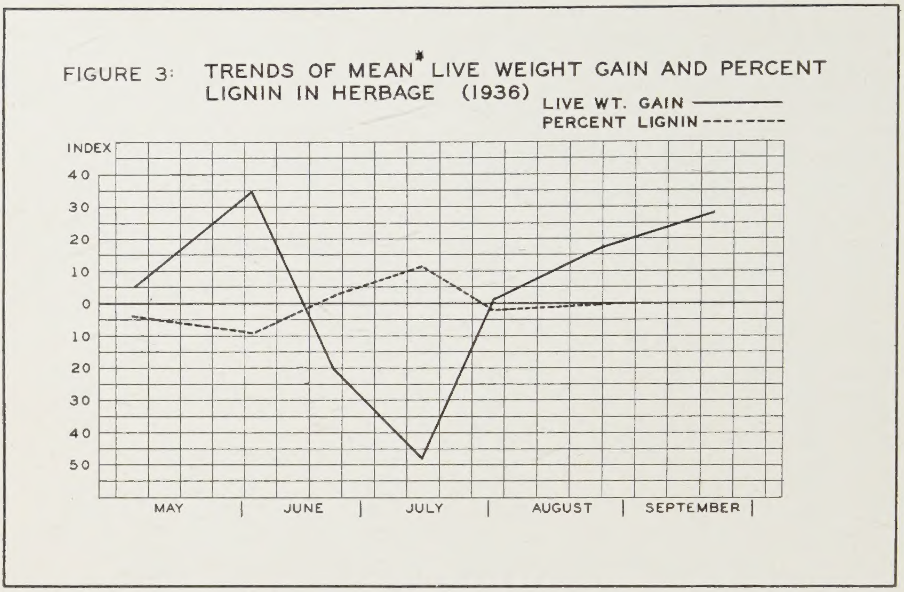
Date of clipping	Lot No.	Initial weight (g.)	Dry matter consumption (g.)	Observed gain (g.)	Gain adjusted for differences in initial weight and dry matter consumption*
May 12, 1936	1	1278	3093	203	215
June 3, 1936	2	1242	2762	167	230
June 20, 1936	3	1341	3329	197	173
July 9, 1936	4	1303	3249	117	104
July 24, 1936	5	1305	3123	198	205
Aug. 20, 1936	6	1313	3408	277	239
Sept. 10, 1936	7	1355	3225	267	260

Necessary difference between lot mean gains for P .05 = 66.91

* The observed live weight gains are adjusted to remove lot differences in initial weight and dry matter consumption. The adjusted lot gains are those which would have been expected had each rabbit been of the mean initial weight and consumed the mean amount of feed.

These live weight gains clearly show wide differences in nutritive value, as measured by gain between grass grown in mid-summer and that grown in the spring or fall months. While large variations in nutritive value exist between clippings representing herbage grown at various times throughout the year, the analyses (Appendix Table I) show no difference of sufficient magnitude in any constituent except lignin to account for these variations. There is a slight diminution in the fibre content in the August 20 and September 10 clippings which may in part account for their superior nutritive value. That fibre differences cannot explain the high feeding value of the May 12 and June 3 clippings is apparent when it is noted that their fibre contents are practically the same as those giving poor growth. Morris, Wright and Fowler (10) have reported that the proteins of spring grass are more valuable for milk production than those of fall grass. This difference in quality of protein may explain in part the similarity between the spring and fall cut herbage even though the former had the higher fibre content. It would seem that the nature and not the amount of the less digestible carbohydrates might, however, be the factor responsible for the observed changes.

As the June 3 and July 9 clippings, while representing only 10 days growth each, were rapidly approaching maturity a change in the nature of the less digestible carbohydrates might be the factor responsible for the observed lowered nutritive value. This is in agreement with the findings of Woodman and Stewart (21) that the manner of deposition of ligno-cellulose, as well as its amount, is responsible for the change in digestibility. Figure 3, in which percentage lignin in the feed and live weight gain per lot are plotted, shows that a small increase in lignin would seem to be accompanied by a large decrease in nutritive value.



°Mean 28-day gain of rabbits = 203·7 gms.; Mean percentage lignin for seasons 11·54%

DIGESTIBILITY STUDIES

In an attempt to obtain an understanding of some of the factors responsible for the observed differences in live weight gains, two sets of digestibility studies were carried out.

In the first, 3 selected rabbits from each lot in Trial A were employed taking the last two weeks of the growth trial as the collection period. Faeces were collected daily, acidified with 1% acid alcohol, dried in fine wire trays in a hot-air dryer and ground in a Wiley mill. Aliquots of the ground faeces from the 3 rabbits on each lot were composited for chemical analyses. The composition of the feeds and faeces are given in Appendix Tables I and II respectively.

Digestibility coefficients of the various food fractions are given in Table 3.

Table 3.—Apparent digestibility coefficients

Lot No.	Lot I	Lot II	Lot III	Lot IV	Lot V	Lot VI	Lot VII
Date of clipping	May 12	June 3	June 20	July 9	July 24	Aug. 20	Sept. 10
Dry matter	44	44	44	38	45	44	47
Nitrogen	64	70	60	60	62	53	66
Ether extract	35	39	10	16	18	18	30
Crude fibre	24	21	22	21	23	21	13
N-free extract	45	41	48	38	37	53	56
Lignin	2	5	7	0	3	3	—
Cellulose	27	30	25	14	28	27	34
Other carbohydrates	66	53	69	66	70	76	66

An examination of the apparent digestibility data indicates that in certain fractions there may be a marked mid-seasonal falling off in digestibility.

To investigate further the findings of the growth and digestibility studies, the clippings of May 12 and July 9, which, while very similar in chemical composition, except in lignin content, had shown markedly different nutritive value and digestibility, were compared in a second feeding trial in which the same rabbits were fed successively on these two clippings. Grass from the May 12 clipping was fed first, followed after an adjustment period by that of the July 9 clipping. The preliminary and collection periods were each of 10 days duration. Feed intake was held constant at 110 grams per rabbit daily.

Allotment data and live weight gains are given in Table 4.

TABLE 4.—ALLOTMENT DATA AND LIVE WEIGHT GAINS DURING 10-DAY COLLECTION PERIOD

Rabbit No.	63	64	61	62	75	76	Average
	gms.	gms.	gms.	gms.	gms.	gms.	gms.
May 12 clipping—							
Initial weight	1592	1440	1651	1584	1555	1452	1546
Gain in weight	74	52	11	35	15	20	34
July 9 clipping—							
Initial weight	1650	1550	1759	1666	1530	1474	1605
Gain in weight	−41	−24	−95	−35	−87	−71	−59

Feed and faeces analyses are given in Appendix Tables III, IV and V.

The apparent digestibility coefficients of each fraction are summarized by lots in Table 5.

TABLE 5.—SUMMARY OF APPARENT DIGESTIBILITY COEFFICIENTS

Coefficient of digestibility of	May 12 grass (mean of 6) %	July 9 grass (mean of 6) %	Standard deviation σ	Necessary difference between lot means
Dry matter	45	40	1.8	2.3
Nitrogen	63	59	1.1	1.4
Ether extract	63	34	5.8	7.4
Crude fibre	31	21	3.0	3.8
N-free extract	39	40	2.1	2.6
Lignin	−7	−5	5.3	6.8
Cellulose	27	24	2.4	3.0
Other carbohydrates	68	72	4.5	5.7

Necessary difference between means of 6 $= \frac{\text{S.D}}{\sqrt{6}} \times \sqrt{2} \times t$

(t = 2.201 for P .05 when n = 11)

The results of this trial substantiate those of the previous one, both in respect to live weight gains and digestibility of the different food fractions. The chemical analyses, other than lignin, show no difference large enough

to explain the differences in digestibility. That an increase of only 3 absolute per cent in lignin content could so adversely affect digestibility would indicate that the manner of deposition of lignin as well as its amount is of nutritional significance (20).

DISCUSSION

The above growth and digestibility studies clearly indicate that marked seasonal changes in nutritive value do occur even in herbage representing only 10 days growth. A progressive falling off in nutritive value during the summer months and a return to that of spring grass with better herbage growing conditions in the fall is clearly shown.

Dry matter, nitrogen, cellulose and nitrogen-free extract showed gradual decreases in digestibility as the season advanced followed by a complete recovery in the fall months. Crude fibre digestibility was variable and showed no definite trend and no differences which might explain observed differences in nutritive value. The digestibility of the "other carbohydrates" fraction, while variable, was always of high order. The almost complete recovery of lignin is in agreement with the observations of Maynard (9) and Rogozinski and Starzewska (12) that lignin is undigested.

No chemical fraction, except lignin, shows a trend which might explain these seasonal changes in digestibility. It would seem that the relatively small increase in lignin in mid-summer is responsible for a considerable decrease in digestibility. The effect on the cellulose fraction is in agreement with the statement of Maynard (9) that lignin is not only unattacked itself but occludes from the action of digestive bacteria and enzymes the cell wall with which it is infiltrated as well as the cell contents. As the grasses from the June 3 and July 9 clippings, while representing only 10 days growth, were rapidly approaching maturity, a change in the availability of the carbohydrate fractions might account for their lowered nutritive value.

SUMMARY AND CONCLUSIONS

The limitations of the standard feedingstuffs analysis as an indication of the feeding value of pasture herbage as measured by the growth of rabbits is shown. The modified feedingstuffs analysis as proposed by Crampton and Maynard (4) is used in an attempt to explain the observed seasonal changes in nutritive value.

A progressive decline in growth promoting value and digestibility of herbage from spring until mid-summer and a complete recovery in both respects in the fall grown material is noted. It is seen that marked differences in nutritive value may exist between herbage representing only 10 days growth according to the period of the season in which it is grown.

The effect of small increases in lignin upon the digestibility of the various feed fractions would indicate that it is not only the amount, but also the mode of deposition, of lignin that determines the extent of its effect upon digestibility and nutritive value of pasture herbage.

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Appendix Table 1.—Feed analyses (dry matter basis)

Lot No.	Lot I	Lot II	Lot III	Lot IV	Lot V	Lot VI	Lot VII
Date of clipping	May 12	June 3	June 20	July 9	July 24	Aug. 20	Sept. 10
Nitrogen	4.1	4.5	3.9	3.8	3.8	3.8	4.4
Ether extract	5.1	4.8	4.2	4.3	4.3	4.7	5.4
Total ash	10.0	9.1	8.9	9.0	9.1	9.3	11.3
Crude fibre	22.5	21.9	21.8	22.4	22.1	19.3	17.1
N-free extract*	37.0	36.1	40.7	40.6	40.8	43.0	38.7
Lignin	11.1	10.6	11.9	13.0	11.2	11.5	(8.1)†
Cellulose	25.2	26.8	24.9	23.8	25.5	23.2	23.6
Other carbohydrates**	23.0	20.6	25.1	26.2	26.2	27.6	20.7

* N-free extract = Dry matter—[(nitrogen $\times$ 6.25) + ether extract + total ash + crude fibre].

** Other carbohydrates = Dry matter—[(nitrogen $\times$ 6.25) + ether extract + total ash + lignin + cellulose].

† As analyses of faeces after the completion of the trial led to this value for lignin being questioned as unduly low and as a value obtained on a later analyses would be unsatisfactory on account of evidence from this laboratory that lignin tends to increase on storage, it is omitted. The omission of this value does not in any way alter the conclusions that might be drawn from the results.

Appendix Table 2.—Faeces analyses* (dry matter basis)

Lot No.	Lot I	Lot II	Lot III	Lot IV	Lot V	Lot VI	Lot VII
Date of clipping	May 12	June 3	June 20	July 9	July 24	Aug. 20	Sept. 10
Nitrogen	2.7	2.4	2.8	2.5	2.6	3.1	2.8
Ether extract	5.9	5.3	6.7	5.9	6.4	6.9	7.2
Total ash	10.7	10.3	9.2	10.0	10.4	10.3	14.2
Crude fibre	30.3	31.1	30.0	28.8	31.0	27.0	28.3
N-free extract	36.4	38.3	36.7	40.0	36.0	36.2	32.6
Lignin	19.4	18.2	19.6	21.0	19.6	21.1	—
Cellulose	33.0	33.8	33.2	33.2	33.0	30.3	29.5
Other carbohydrates	14.2	17.4	13.9	14.6	14.4	11.9	13.2

* Each sample is a composite of faeces from 3 rabbits.

Appendix Table 3.—Feed analyses (dry matter basis)

Clipping	Nitrogen	Ether extract	Total ash	Crude fibre	N-free extract	Lignin*	Cellulose*	Other carbohydrates
May 12	4.1	5.1	10.0	22.3	37.0	11.7	25.4	22.2
July 9	3.8	4.3	9.0	22.4	40.6	14.7	26.9	21.4

* The lignin and cellulose values are slightly different than those reported in Appendix Table 1. This digestibility study was carried out some 8 months after the former analyses had been obtained and as work in this laboratory indicates that lignin values change on storage the analyses given are those obtained at the time of the feeding trials.

APPENDIX TABLE 4.—FAECES ANALYSES (DRY MATTER BASIS). MAY 12, 1936 CLIPPING

Rabbit No.	63	64	61	62	75	76
Nitrogen	2.7	2.7	2.8	2.7	2.8	2.8
Ether extract	3.4	3.1	3.5	3.3	3.4	3.5
Total ash	9.9	10.0	10.3	10.0	9.7	10.1
Crude fibre	27.6	28.3	26.3	29.4	28.2	28.8
N-free extract	42.0	41.4	42.6	40.3	41.1	40.4
Lignin	21.6	21.5	21.6	23.8	24.7	23.8
Cellulose	34.5	33.4	32.6	34.2	34.2	32.7
Other carbohydrates	13.6	14.8	14.8	11.8	10.5	12.7

APPENDIX TABLE 5.—FAECES ANALYSES (DRY MATTER BASIS). July 9, 1936 CLIPPING

Rabbit No.	63	64	61	62	75	76
Nitrogen	2.6	2.6	2.6	2.6	2.6	2.6
Ether extract	5.5	5.1	4.1	4.7	4.6	4.6
Total ash	8.9	8.7	8.7	9.3	9.0	9.0
Crude fibre	29.6	29.2	29.8	29.7	29.2	29.2
N-free extract	39.9	40.1	41.2	40.3	41.1	41.0
Lignin	25.5	26.1	26.9	26.5	25.8	24.7
Cellulose	33.7	34.4	34.3	35.6	33.1	34.0
Other carbohydrates	10.3	9.2	9.8	8.0	11.4	11.5

SOME FACTORS AFFECTING THE DROPPING OF McINTOSH APPLES

G. H. Dickson[1]

Horticultural Experiment Station, Vineland Station, Ontario

[Received for publication —Aug. 21, 1939]

The dropping of McIntosh apples as they approach maturity has long been recognized as a weakness of the variety and one which has frequently resulted in serious losses to the growers. MacDaniels (8) suggests that this dropping may not be an unmitigated defect inasmuch as it tends to limit the acreage of McIntosh that one man can handle, and so encourages the planting of other varieties. He also finds that this dropping prevents the fruit from becoming overmature on the tree with resultant breakdown in storage, as is the case with Cortland, which does not drop. In some places the practice of early picking and sun colouring is being developed (5). Too frequently the grower, in his anxiety to harvest the crop before any drop occurs, and realizing full colour may be obtained through sun colouring, picks the fruit before it attains desirable quality. Further work seems necessary therefore in order to develop some cultural system whereby it may be possible to harvest McIntosh with a maximum of quality and a minimum of loss from dropping.

In reviewing some of the literature it is evident at once that, as yet, no one worker has sufficient experimental data on which to base conclusions concerning the influence of cultural treatments on the dropping of McIntosh. It is of considerable interest however to know that several workers in widely separated areas making observations on this problem arrived at similar conclusions. This unanimity of conclusion although lacking in adequate experimental background would seem of sufficient weight to warrant careful examination.

> MacDaniels (7) finds, "A comparison of the abscission zones of fruits from McIntosh trees that showed marked differences in the time of dropping their fruit or differences in ease of separation did not bring out any marked structural differences. These comparisons included trees that had been moved recently and those that had not, trees with high nitrate and trees with low nitrate, and trees with heavy mulch and in sod. There was an indication that the tissues of cluster base, pedicel and abscission zone of the moved trees were harder than in the others. This condition would be expected as it is generally true that plants making slow growth and probably with a low nitrate and high carbohydrate ratio produce harder tissues with more sclerenchyma than more rapidly growing plants. The effect of this condition might well be to produce a stronger abscission zone as well as affect the physiology of abscission. A more extensive study of trees showing differences in abscission is needed to determine what these effects may be."

> MacDaniels (7) also notes, "Thus it has been observed that McIntosh fruits borne on trees which have been recently moved and are somewhat under-vigorous, separate from the spurs with much more difficulty than on trees that have not been moved." Developing this idea further (8) he states, "The same thing is true of trees which are somewhat starved for nitrogen and are making relatively

[1]Assistant in Hardy Fruit.

weak growth. It would seem that in trees where there is apparently an excess of carbohydrates as compared to nitrogen, more woody tissue is formed so that the abscission zone is not so easily cut across. In fertilizer experiments carried on by Dr. Heinicke, it has also been clear that trees receiving an excess of nitrogen shed their fruits more readily than those which had normal or slightly subnormal nitrogen. This suggests that in growing McIntosh nitrogen should be applied with caution, or as horticulturists say, the variety should be grown somewhat on the 'hard' side rather than with an excess."

Palmer (9) found in British Columbia that orchards well supplied with nitrogen had to be picked earlier than other orchards not receiving such good treatment. Recommendations were made to growers that the McIntosh trees in the best areas of an orchard be harvested first as those on the poorer trees would hang longer.

Southwick (13, 14) reports, "The dropping severity of a single tree or an entire block is not constant from year to year.

"Dropping was more severe with trees grown under a high state of fertility. Complete fertilizer plots suffered more dropping than nitrogen only plots. Nevertheless, high nitrogen availability as found under a heavy mulch system seemed to lead to excessive dropping of fruit.

"With a few exceptions the percentage of dropping was found to increase with increasing yield. This was true for plots as well as for individual trees.

"Seed number was positively correlated with date of drop of apples from individual trees. (The presence of many seeds delayed dropping.)"

CULTURAL TREATMENTS

McIntosh is one of the varieties used in a cultural experiment being conducted at the Ontario Horticultural Experiment Station. A preliminary report of this experiment appeared in 1937 (1). The cultural treatments are as follows:—

The orchard is ploughed in early spring and receives the usual cultivations until a good seed bed is worked up. About May 15 half the orchard (2 plots) is sown to a green manure crop (minimum cultivation treatment). The remainder of the orchard (2 plots) is kept cultivated until July 15 and sown to the same green manure crop (regular cultivation treatment).

RESULTS

Effect of Nutritional Conditions on Dropping

Beginning with the 1935 crop, careful estimates of the McIntosh "drops" have been made. In 1938 the differences in the weight of drops from adjacent trees under different cultural treatments were most striking.

Minimum cultivation—	165 lbs. picked.	2 lbs. drops.	Fair colour.
Regular cultivation —	155 lbs. picked.	30 lbs. drops.	Large green.
Minimum cultivation—	180 lbs. picked.	5 lbs. drops.	Good colour.
Regular cultivation —	95 lbs. picked.	190 lbs. drops.	Fair colour.

Following this observation a comparison of drops for the different plots for the 4 years 1935–38, was made. This comparison has brought out some interesting information. Under regular cultivation a greater total yield was obtained but the percentage of drops was so high that the weight of picked fruit was greater in the plots receiving minimum cultivation. Colour was also much better in the plots receiving minimum cultivation (this held for all varieties—see Colour Plate showing differences in McIntosh and Spy between treatments) although the size of fruit was somewhat reduced.

To obtain a better appreciation of the influence of yield and treatment on drops, the results are first presented by plots and years. In a consideration of these results (Table 1) it should be realized that these data were taken for a cultural experiment. As only one picking was made each year for McIntosh an attempt was made to harvest the fruit when the orchard as a whole had developed desirable colour without sacrificing too much from drops. Since the fruit on the minimum cultivation plots coloured earlier it could have been picked several days before the fruit on the regular cultivation plots, in which case the differences in drops between these two treatments might have been even greater. In future, harvesting will be done with consideration to the plots rather than to the orchard as a whole. In attempting to improve colour and reduce drops by cultural means, quality must not be sacrificed by picking too soon or by unduly reducing tree vigour. Haller and Magness (4) have found that fruit grown with a small number of leaves was of very poor quality.

Table 1.—Average annual yields (lbs.) per tree for McIntosh apple under different cultural treatments

—	Regular cultivation				Minimum cultivation			
	Plot 4 (11 trees)		Plot 5 (8 trees)		Plot 1 (16 trees)		Plot 8 (6 trees)	
	Picked	Drops	Picked	Drops	Picked	Drops	Picked	Drops
1935	94	65	83	38	40	26	8	18
1936	55	31	70	22	114	17	147	34
1937	123	148	59	132	104	35	26	22
1938*	56	20	81	81	143	18	163	64
Total	328	264	293	273	401	96	344	138

* 6 and 3 trees respectively were removed in 1938 from Plots 1 and 5 for highway.

Summarizing the above records to show the effect of cultural treatments on total yield and drops for the whole four crops the following figures are obtained:

—	Total	Picked	Drops	Drops
				%
Regular cultivation	579	311	268	46
Minimum cultivation	489	372	117	24

Top—McIntosh *Bottom*—Spy

Twelve apples on the left from plots having a low nitrate supply and receiving minimum cultivation.

Twelve apples on the right from plots having a moderate nitrate supply and receiving regular cultivation.

In the conclusions from the earlier report (1) it was suggested, from soil nitrate determinations made in 1936, that the limiting factor for yield and colour of fruit and foliage might be nitrates. Roberts (12) finds that the colour of the fruit varies inversely with the nitrogen content.

Nitrate determinations for 1937 and 1938 bear out the 1936 results and continue to show low nitrates in mid-season under minimum cultivation (Figure 1)[2]. This low nitrate condition may account for the lower percentage of drops under minimum cultivation, as is also suggested by the observations of MacDaniels (7, 8), Palmer (9), and Southwick (13, 14).

Moisture determinations for the same period show seasonal variations depending somewhat on the vigour of the green manure crop at the time the determinations were made. It is interesting to note that in all cases the minimum cultivation plots had a somewhat higher moisture content at the end of the season than did the regular cultivation plots (Figure 2). This suggests that moisture as well as nitrates (12) may have influenced colour. Kimball (6) found moisture supply to be the main factor in controlling fruit colour in an orchard growing on Plainfield sand.

As another example of non-dropping in McIntosh the following case may be cited. In 1932 a grower sent scions of a non-dropping McIntosh to this Station for trial. When the scions from this tree fruited on Station trees the apples dropped quite as badly from this "sport" (?) as from any normal McIntosh. A check of the original tree showed it to be growing on a sheet-eroded knoll on which no vegetation was growing (September). The tree itself was about half the size of nearby trees of the same age. It would be classed as a typical undernourished tree, and under these conditions the apples hung on solidly.

Effect of Low and High Yields on Dropping

In Table 1, and as pointed out by Southwick also (13), the percentage dropping was found to increase with increasing yields. Perhaps this ought to be qualified somewhat. The percentage of drops increased with increasing yields induced by better cultural or growth conditions. (The addition of barnyard manure across four rows of this cultural experiment indicated this to be true. Results are still too incomplete to include here.) But the percentage of drops is lower where the increased yield is due to "on" year cropping, as distinguished from increased yields due to cultural conditions.

In a block of approximately 120 McIntosh trees planted in 1922 a record of drops has also been kept and is as follows:

—	Average yield per tree (lbs.)	Picked	Drops	Drops
				%
1936	155	98	57	36
1937	390	300	90	23
1938	246	162	84	34

[2] In preparing the 1936 nitrate figure for Scientific Agriculture 17 : 11, 1937. an error was made showing nitrates 10 times too high. Correction has been made for this paper.

Other things being equal, it would be expected that under similar orchard treatments a heavy crop (1937) would be a greater drain on nutrients than a lighter one (1936 and 1938). At any rate the percentage drop was less in 1937.

Effect of Colour Type on Dropping

Then there is the question of type of fruit, streak and blush types. In the 120-tree McIntosh orchard previously referred to, colour records have been kept. Twenty-four trees have consistently borne blushed fruits and 23 produced dull streaked fruit. Of the remainder, 32 were streaked but coloured well, while 41 varied from good streak to blush depending on seasonal factors. From casual observations it was believed that the streak type dropped more readily, and much substantiating evidence could be assembled to confirm such an idea. The record of four trees in Row 22 is as follows:

Fruit type	Total yields (lbs.), 1935–38	Drops
		%
Tree 10—Good colour, slight streak	993	37.0
12—Good colour, slight streak	825	33.9
14—Dull streak	396	74.0
16—Dull gray streak, large	852	62.4

To offset this however two adjoining trees in row 16 show practically the same yield, 757 and 751 lbs. with 36.6% and 34.0% drop respectively. One was of excellent colour and size, the other was the large dull gray streak type. Using the extremes, Blush (24 trees) and Poor Streak (23 trees) there were no real differences as shown in Table 2.

Table 2.—Colour type in relation to the dropping of McIntosh apples

	Blush			Streak		
	Picked	Drops	Drops	Picked	Drops	Drops
			%			%
1935	55	40	42	65	43	40
1936	127	76	37	106	65	40
1937	185	87	32	204	129	35
1938	90	116	56	88	91	51
Average	114	80	42	128	82	41

Effect of Seed Content on Dropping

Regarding the relation of seeds to pre-harvest McIntosh drop, Southwick (14) opens up an interesting line of thought. MacDaniels (letter) suggests that a high seed content builds up more and stronger tissue in the pedicel. But may this not be secondary and the whole problem related

rather to nutrition? Gourley (3) states that "as a rule the sooner the thinning is done after the June drop, the better will be the result, since by so doing the developing seeds are prevented from draining the energy of the tree." Gourley quotes Green as pointing out that male asparagus plants yield approximately 50% more in a season than female plants. The increased yield of male asparagus plants has been confirmed many times since. Robb (11) in recording confirmatory evidence of his own, reports similar findings of a number of investigators. Gourley (3), quoting Bigelow and Gore, U.S. Dept. Agric. Bur. Chem. Bull. 97, and discussing a table on the average composition of six varieties of peaches at different stages of growth says,

> "It is well to observe also that solids in the flesh remained fairly constant throughout the development of the fruit, the variation ranging from a total of 14 to about 17 per cent, a difference of only 3 per cent, while the solids in the stones constantly increased from about 9.3 per cent at the June drop period to nearly 67 per cent at the market ripe period. These figures therefore, furnish a scientific basis for early thinning, also for the frequent observation that the development of a large number of pits makes a heavy demand for plant food."

Dickson (2) working with plums found that, while thinning did not materially influence the total yield in pounds the size of the fruit was improved. Unthinned trees produced more individual fruits which in turn resulted in a comparatively devitalized condition as indicated by delayed bloom the following season, and with tender varieties such as Reine Claude, definite susceptibility to winter injury.

This of course refers to stone fruits. Fruit production in pome fruits also reduces tree size but evidence of seed influence here seems lacking. Palmer and Fisher (10) found that, "heavy thinning resulted in increased trunk cross sectional area of the McIntosh and Delicious varieties without materially increasing their height or spread". Upshall (15), to show the effect of early fruiting on shape of tree, used two adjacent Melba trees which were of equal size when planted. Both received identical cultural treatments but one tree was not allowed to fruit, all the blossoms being removed in the spring; the other was allowed to fruit naturally. At the end of the eighth year this latter tree had borne 99 pounds of fruit and was about 40% smaller than the non-fruiting tree. Evidently the production of fruit has a very considerable dwarfing effect on growth but what proportion of this effect is due to seed development is unknown.

Whether extra seeds in a fruit cause stronger tissue development, or absorb more nitrates and thus lower the ratio of nitrates to carbohydrates is perhaps immaterial. The fact remains that the many-seeded fruits do not drop as readily. Because of this, special provision for cross-pollination of McIntosh should be made even though extra thinning may be necessary. Good pollen varieties should be selected to plant with McIntosh and strong colonies of bees should be provided to distribute this pollen.

CONCLUSIONS

1. Minimum cultivation reduced the amount of nitrates in the soil, especially in midseason. As a result of the lowered nitrate supply the percentage of McIntosh drops was reduced and the colour was much improved.

2. The percentage of drops increased with increasing yields induced by better cultural or growth conditions, but the percentage of drops was lower where the increased yield was due to "on" year cropping.

3. So-called non-dropping "sports" of McIntosh may be the result of nutritional factors rather than of mutation.

4. Although individual trees of streak McIntosh may drop badly, the percentage drops from Blush and Streak types over a period of years has been the same.

ACKNOWLEDGMENTS

The writer wishes to acknowledge the assistance of Mr. O. A. Bradt in the preparation of the moisture and nitrate charts, of Mr. E. F. Palmer and Dr. W. H. Upshall for suggestions in the preparation of the paper and of other members of the Station Staff who have helped in the taking of records.

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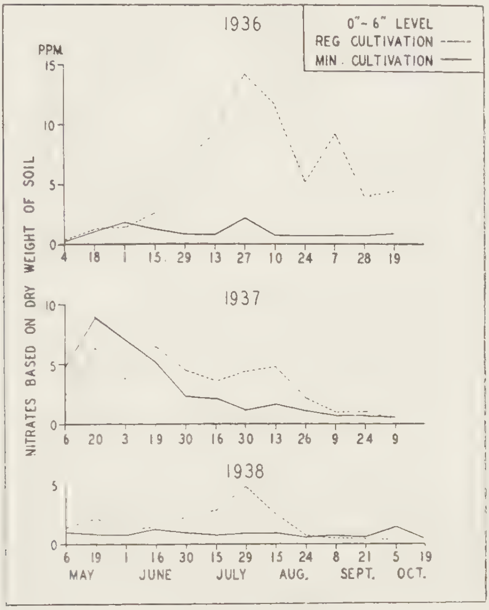
1936
0"-6" LEVEL
REG CULTIVATION -----
MIN. CULTIVATION ——
PPM
NITRATES BASED ON DRY WEIGHT OF SOIL
1937
1938
MAY
JUNE
JULY
AUG.
SEPT.
OCT.

Fig. 1.

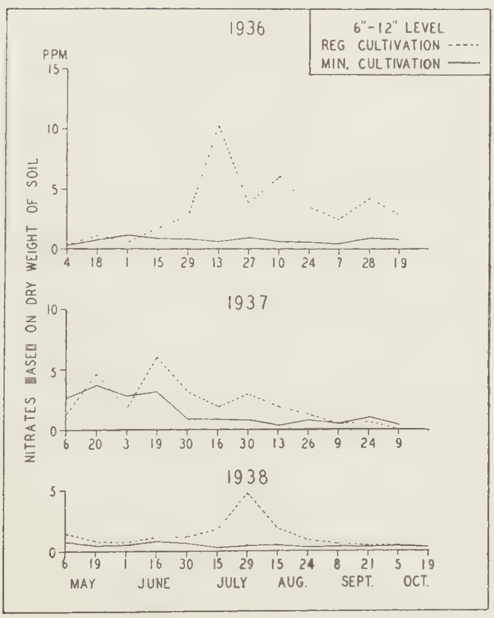
1936
6"-12" LEVEL
REG CULTIVATION -----
MIN. CULTIVATION ——
PPM
NITRATES BASED ON DRY WEIGHT OF SOIL
1937
1938
MAY
JUNE
JULY
AUG.
SEPT.
OCT.

Fig. 2.

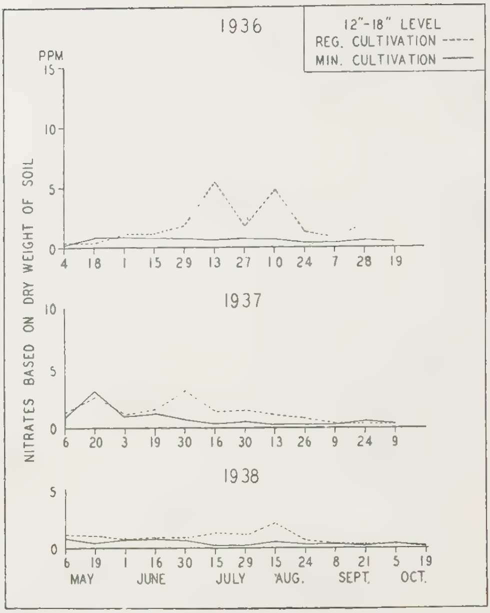

Fig. 3.

Figures 1, 2, 3. Nitrates in p.p.m. based on dry soil, at different depths under regular and minimum cultivation treatments 1936, 1937, and 1938.

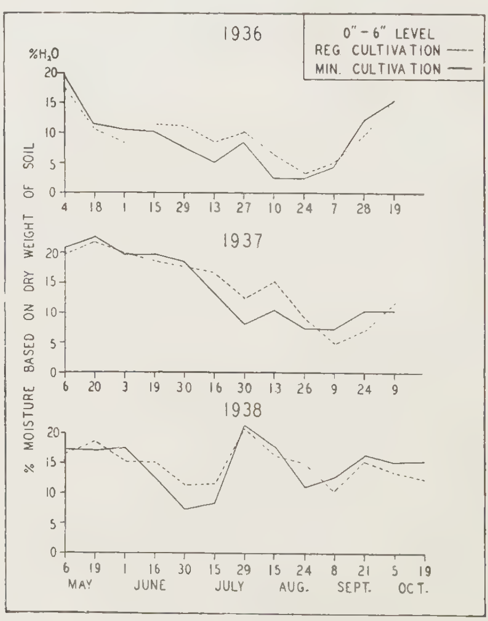

Fig. 4.

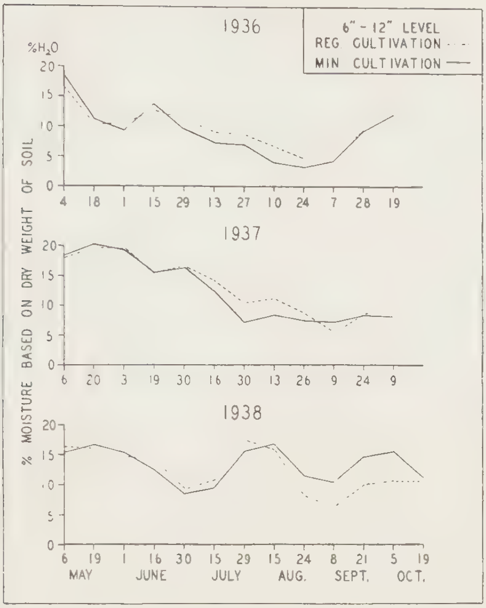

Fig. 5.

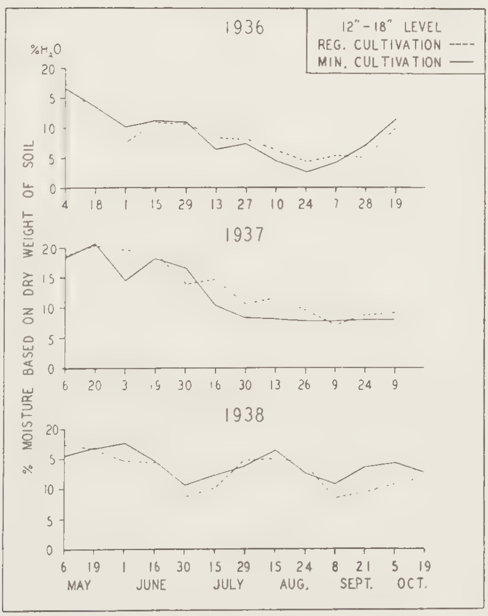

Fig. 6.

Figures 4, 5, 6. Percentage moisture based on dry soil at different depths under regular and minimum cultivation treatments 1936, 1937, and 1938.

VERTICILLIUM WILT OF POTATOES IN PRINCE EDWARD ISLAND[1]

G. W. Ayers[2] and R. R. Hurst[3]

Dominion Laboratory of Plant Pathology, Charlottetown, P.E.I.

[Received for publication April 1, 1939]

THE WILT PROBLEM AND ITS IMPORTANCE

During the past few years an appreciable amount of wilt has been reported in Irish Cobbler seed potatoes in Prince Edward Island. The causal agent had not been determined up to 1937 when it was found through numerous isolations and pathogenicity tests that a *Verticillium* species was the organism involved. Wilt disease, while never serious in P.E.I., has nevertheless been on the increase, becoming more widespread during recent years, until in 1937 it was recognized as an important problem. *Verticillium* wilt was first described in Germany in 1879 by Reinke and Berthold (8) who found it in the potato. Rudolph (9) states that the disease has been reported definitely on over 120 species of plants included in 35 widely unrelated families and 18 orders. It occurs widely in Northern United States and has been reported quite extensively at times in the provinces of Quebec and Ontario. It has also been identified in Australia, New Zealand, Greece, England, France, Italy and Germany.

The chief economic effect of wilt in potatoes is evident in reduced yields of marketable tubers.

The main purpose of this paper is to clarify the confusion as to the main cause of wilt in Prince Edward Island, and to set forth the difficulties and the possible solution of obstacles encountered in the eradication of this malady.

The seed potato inspection service has found this disease to be difficult to detect in the field, being complicated in its time of appearance and type of symptoms by a number of factors. It has been found in the past that wilt symptoms vary in their time and mode of expression from year to year, and also from day to day, depending on climatic conditions. Generally speaking, extremely dry weather is favourable to ready detection of wilt, while moist conditions modify the appearance of the wilted plants and the disease is therefore not easily observed. The summer of 1937 was quite dry and individual plants infected with *Verticillium* showed a general flagging. The following year being very moist resulted in an entirely different type of symptom expression. The wilt followed the more natural trend generally associated with *Verticillium* infection and characterized by

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[1] Contribution No. 587 from the Division of Botany and Plant Pathology, Science Service, Department of Agriculture, Ottawa, Canada.

[2] Junior Pathologist.

[3] Officer-in-Charge, Dominion Laboratory of Plant Pathology, Charlottetown, P.E.I.

a progressive flagging from the base of the plant upward. In an early maturing field such plants may be quite easily considered as having reached a certain stage of normal senescence. The problem of estimating percentages of wilt may be further complicated by attacks of early or late blight. Such was the case in 1938 when many fields were so severely affected that estimates of wilt were impossible. Variation in temperature and moisture conditions from day to day are also worthy of consideration. On a hot sunny day wilt-infected plants display a noticeable flagging, while on a cool overcast day such plants often recover to such an extent that the wilt condition is not clearly evident.

Apart from the above considerations, time of appearance, and development of wilt are important factors in estimating percentages. Observations made lead us to believe that wilt attacks are evident after the first week in August in each year. It has been observed that diseased fields always show an increased percentage of infection as the season advances.

The inspection service has done a great deal to familiarize investigators with the type of symptoms induced by the wilt organism, but due to the difficulties outlined above an accurate field estimate of this disease is impossible. The most practical means of eliminating this trouble, then, would be for growers to obtain their seed from stock which has been given an absolutely clean reading in the preceding year. In most cases where fields have been rejected for wilt, traces of infection have been reported in the previous year's stock.

DISTRIBUTION OF WILT

Data have been compiled relative to the severity and distribution of wilt during the past 4 years. These figures are taken from the seed potato inspection reports and are indicative of the extent of this disease in Prince Edward Island.

The data in Table 1 would seem to imply that wilt is very prevalent. However, it is felt that many fields recorded as slightly affected were merely flagged due to drought and heat. Especially is this believed to be true in the case of Green Mountain readings, as *Verticillium* has never been isolated from any plants of this variety. On the other hand if constant surveillance were made of all fields during the month of August it is felt that many fields of Irish Cobblers showing only slight wilt infection at time of inspection would be rejected on a later date.

More wilt was reported in 1937 than in the immediate preceding years due it is thought to the dry weather, resulting in very evident symptom development.

Information in Table 2 indicates that wilt has been more severe in Prince County than in Queens or Kings. It has also been found that epidemics seem to be confined to certain districts, due no doubt to exchange of seed in these localities.

TABLE 1.—THE PREVALENCE OF WILT IN THREE VARIETIES OF CERTIFIED SEED POTATOES OVER A PERIOD OF FOUR YEARS*

—	1935			1936			1937			1938		
	I. C.[1]	G. M.[2]	B. T.[3]	I. C.	G. M.	B. T.	I. C.	G. M.	B. T.	I. C.	G. M.	B. T.
Total fields inspected	2,411	910	33	2,208	947	42	2,587	936	80	2,418	1,041	43
Total fields showing wilt	375	30	0	331	25	4	630	88	12	357	50	6
Percent of fields showing wilt	15.6	3.3	0.0	15.0	2.6	9.5	24.4	9.4	15.0	14.8	4.8	14.0
Fields showing slight wilt infection (below 1 per cent)	355	30	0	316	25	4	588	88	12	334	50	5
Fields rejected for wilt (1 per cent wilt and over)	20	0	0	15	0	0	42	0	0	23	0	1
Per cent of fields rejected for wilt	0.83	0.0	0.0	0.68	0.0	0.0	1.62	0.0	0.0	0.95	0.0	2.33
Average per cent wilt in fields rejected for wilt	5.76	—	—	6.18	—	—	5.36	—	—	7.36	—	4.0

* Data from Seed Potato Inspection Reports. [1] I. C.—Irish Cobblers. [2] G. M.—Green Mountains. [3] B. T.—Bliss Triumph.

TABLE 2.—THE DISTRIBUTION OF WILT IN CERTIFIED IRISH COBBLER SEED POTATOES OVER A PERIOD OF FOUR YEARS*

	1935			1936			1937			1938		
	Prince	Queens	Kings	Prince	Queens	Kings	Prince	Queens	Kings	Prince	Queens	Kings
Passed—												
Total fields inspected	462	973	741	372	878	690	422	1,036	790	381	1,068	672
Fields with wilt infection	244	107	3	195	118	0	229	254	98	166	91	71
Not passed—												
Total fields inspected	47	150	38	49	160	59	66	215	58	82	151	64
Fields with wilt infection	16	5	0	7	11	0	17	31	1	24	3	2
Fields rejected for wilt	16	4	0	6	9	0	15	26	1	20	3	0
Percentage of fields with wilt infection	51.1	10.0	0.4	48.0	12.4	0.0	50.4	22.8	11.7	41.0	7.7	9.9
Percentage of fields rejected for wilt	3.1	0.4	0.0	1.4	0.9	0.0	3.1	2.1	0.1	4.3	0.2	0.0

* Data from Seed Potato Inspection Reports.

TABLE 3.—AVERAGE PERCENTAGE OF WILT IN ALL VARIETIES OF CERTIFIED SEED FROM 1935 TO 1938 INCLUSIVE*

——	1935	1936	1937	1938
Average percentage wilt in total fields inspected	0.084	0.045	0.119	0.070
Average percentage wilt in total fields certified	0.047	0.049	0.079	0.036
Average percentage wilt in total fields rejected.	0.206	0.176	0.306	0.190

* Data from the Seed Potato Inspection Reports.

Table 3 is a statement on the percentage basis of wilt as it occurred in fields of potatoes entered for certification during the past 4 years.

SYMPTOMATOLOGY

The manifestation of this disease was first studied under field conditions on a farm situated at Brackley Point in Queens County. Primary indications of wilt were noted on August 6, 1937 when affected plants showed flagging at the tips of the leaflets. By August 25th, 10% of the plants were definitely wilted, the symptoms progressing from the terminal leaflets towards the main stem. The yellowing of the petiole and main stem was a distinct feature, being accompanied by a brownish discolouration of the vascular tissue. A consistent, though not conspicuous, symptom was the tendency of the lower leaflets to succumb to wilt. It was noted too that a single branch of a plant may be affected while the others remained healthy; or one shoot only may evade the attack. Figure 1 illustrates the manner in which wilt progressed as judged from field symptoms in 1937.

Inasmuch as the affected plants grew in light sandy soil during a period marked by unusually dry weather it is not improbable that they had reacted to the combined effect of drought conditions and the toxic action of the parasite. Plants later grown and infected in the greenhouse showed a much more even progression of wilt from the base of the plant upward. Another symptom of Verticillium wilt, though not consistent, was noted in storage. Many tubers from wilt hills had a black stolon attachment and such tubers when pared showed a distinct browning of the vascular ring (Figure 2). Not all tubers from wilt hills showed these symptoms however and discolouration of the vascular ring is not believed to be a true criterion of the presence or absence of Verticillium wilt infection.

ISOLATION AND PATHOGENICITY TESTS

In order to ascertain the specific organism generally responsible for wilt, representative samples of wilted plants were obtained from 5 severely affected fields located in different districts. Upper and lower stem and tuber tissues were employed for isolation purposes. Such material was

FIGURE 1. Field symptoms in a plant affected with Verticillium wilt.

cultured in 3 types of artificial media, *viz.*, potato dextrose agar, p.d.a. with peptone, and p.d.a. with yeast extract. Plants from all 5 farms yielded identical isolates and the organism was present in both stem and tuber tissues of severely wilted plants. Growth was most prolific on potato dextrose agar.

Giant cultures of the isolate were grown on a medium of sterile wheat and the inoculum thus provided was introduced into 12 pots of sterilized soil (A) in which sets from sound Irish Cobbler potatoes were planted. Twelve similar non-inoculated checks (B) were set up. In addition 12 sets from diseased stock were planted in sterilized non-inoculated soil (C). Planting was done January 6, and on April 9 wilt symptoms were detected on 2 plants of the inoculated series (A). By April 29, symptoms were apparent on 11 plants of (A) and on 4 plants of (C) whereas all plants in the non-inoculated series (B) showed normal development on the same date. Isolation work carried out April 29, May 16, and June 18, resulted in the recovery of the original inoculum from stem tissue of those plants growing

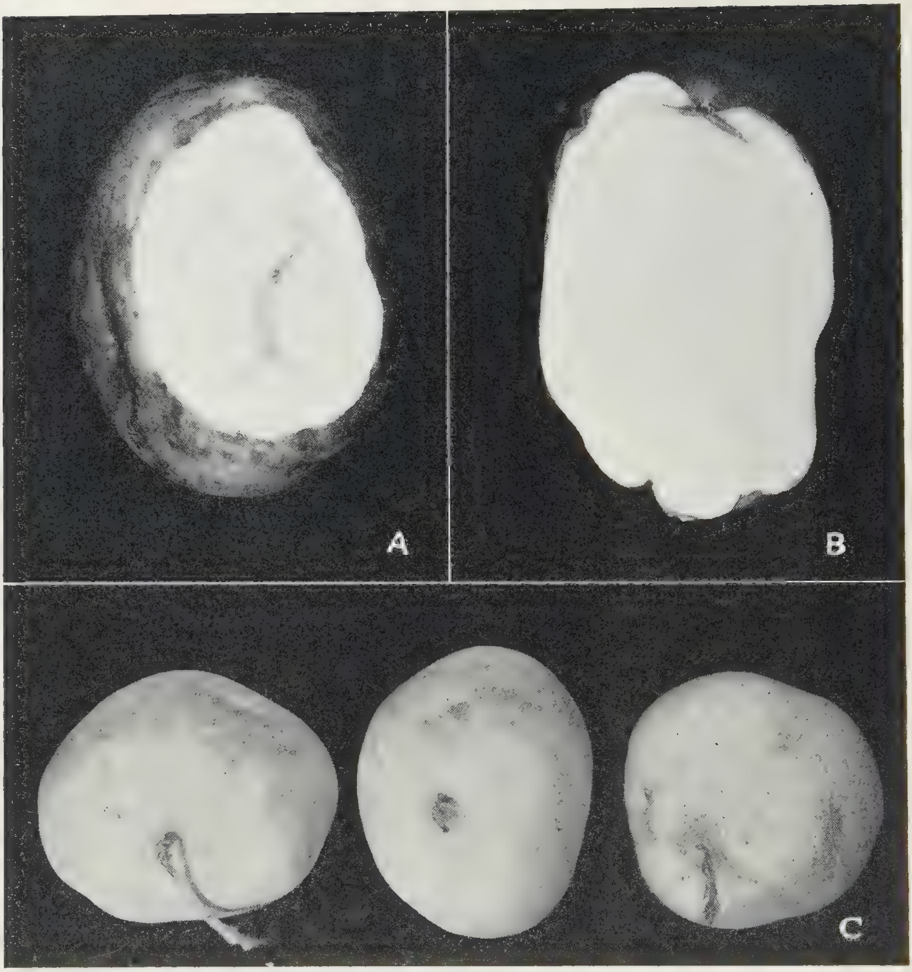

FIGURE 2. Tuber symptoms of Verticillium wilt. (A) and (B) Browning of vascular ring in cross and longitudinal section, (C) Tubers showing blackened stolon attachments.

in inoculated soil (11 plants). Plants of the non-inoculated series (B) which were living on June 18 (10 plants), appeared healthy and according to isolation studies were free from disease.

Only 2 plants of the diseased seed series were tested for presence of the organism. In each case cultures of Verticillium were obtained. Figure 3 shows the condition of 4 plants of each series on April 29, 1937.

Similar studies were carried out with Green Mountain and Bliss Triumph varieties. Eight pots of each variety were planted, 4 inoculated and 4 as checks. All plants of the inoculated series upon re-isolation yielded Verticillium cultures similar to the inoculum. The checks remained healthy.

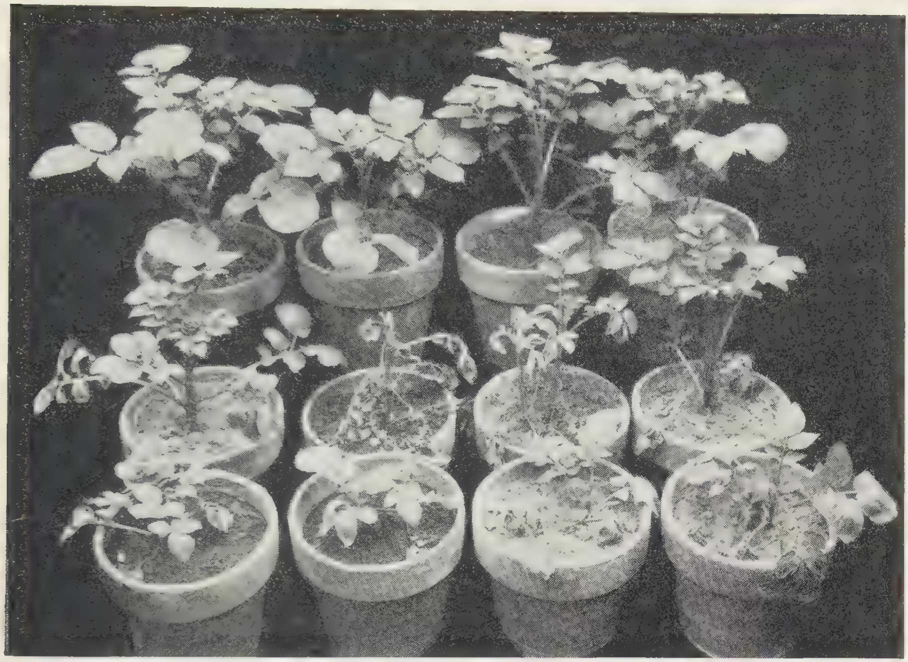

FIGURE 3. Verticillium wilt symptom development. Plants to rear are checks from non-inoculated series (B in text). Plants in second row were grown in Verticillium inoculated soil (series A). Plants to fore are from the diseased series (C).

CAUSE

The organism causing wilt has been identified as *Verticillium albo-atrum* R & B. This classification is based on the description given by Reinke and Berthold (8) and supplemented by various workers since that time.

It is generally accepted that there are two distinct species of Verticillium. *Verticillium dahliae* as described by Klebahn (5) was considered a separate species due to sclerotial formation in culture. Klebahn found that *V. albo-atrum* did not produce sclerotia in culture. Pethybridge (7) supports this view. Rudolph (9) considers there to be but one species, *viz.*, *V. albo-atrum*. Berkeley *et al.* (1) consider both types of Verticillium worthy of specific rank because of proven morphological and physiological differences. They contend that *Verticillium albo-atrum* should be considered to produce specialized "resting mycelium" but not pseudo-sclerotia and that *V. dahliae* should include definite pseudo-sclerotia. Ludbrook (6) agrees with this classification, and further states that *V. dahliae* has a distinctly higher temperature range than *V. albo-atrum*.

The Verticillium isolated in the course of this investigation conformed to the albo-atrum type inasmuch as sclerotial bodies did not form in culture. The organism also agrees more with the temperature relationships of *V. albo-atrum* as described by Ludbrook (6).

Figures 4, 5, 6 and 7 are photomicrographs of *Verticillium albo-atrum* showing conidiophore, spores, darkened hyphae, and hyphae in host tissue. Figure 8 is a photograph of a colony grown on potato dextrose agar.

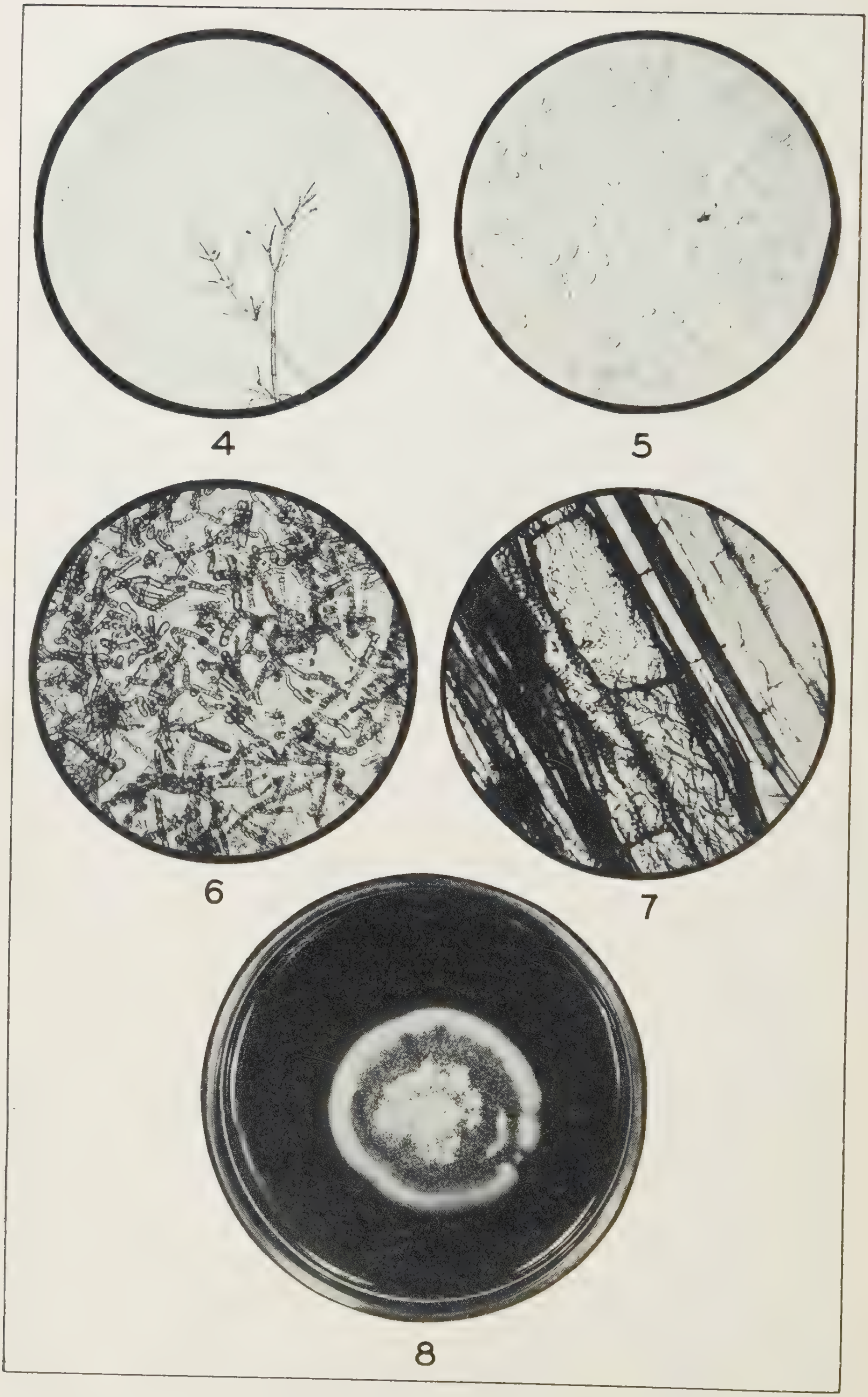

FIGURE 4. Verticillate conidiophore. FIGURE 5. Spores of Verticillium. FIGURE 6. Resting mycelium or darkened hyphae. FIGURE 7. Verticillium hyphae in potato stem tissue. FIGURE 8. *Verticillium albo-atrum* on potato dextrose agar—15 day old culture.

EPIDEMIOLOGY

The development and spread of wilt has been found to be considerably influenced by temperature and to a lesser extent by rainfall. Figure 9 is a growth curve of *Verticillium albo-atrum* on artificial media. Growth was quite good over a wide temperature range of 60–77° F. The maximum temperature for growth was from 87 to 90° F., or 30 to 32° C.; the optimum was between 66 and 70° F. or 19–21° C. Bewley (2) reports an optimum of 23.3° C. for *Verticillium albo-atrum* in culture and a maximum of 30° C.

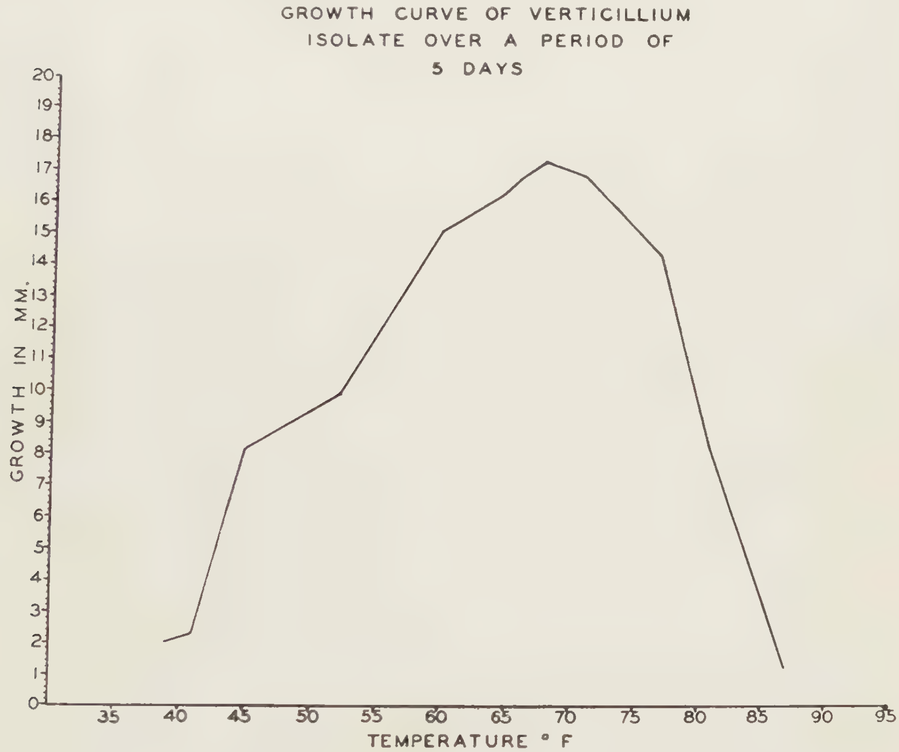

FIGURE 9. Temperature relationships of Verticillium isolate on artificial media.

Most investigators regard drought as distinctly favourable to wilt. Observations made locally would seem to indicate that wilt symptoms become evident at about the same time in a dry year as in a year of heavy rainfall. However symptoms are more pronounced in a dry year. It would seem that this is an effect on the plant rather than on the fungus as excesses of water over and above that required to maintain good growth have had little or no effect on the progress of wilt.

Time of planting has been found to be of importance in wilt development. Diseased seed planted at weekly intervals in the spring of 1938 developed wilt to nearly the same extent. The latter two plantings however did not show symptoms till nearly a week later than the early plantings and the symptoms were at no time as pronounced. Spread of wilt from diseased hills to adjacent healthy hills was evident only in early plantings.

No figures are available as to the longevity of the fungus in the soils of Prince Edward Island. Chamberlain (3) working in New Zealand, states that the fungus will persist in the soil for several years. Eastham (4) of the British Columbia Department of Agriculture reports that Verticillium can live in the soil indefinitely.

It is believed that the greater part of wilt infection encountered in Prince Edward Island originates from diseased seed-stock. The following data, gathered from field inspection reports for Prince County, support this view, and emphasize the importance of using sound seed.

TABLE 4.—SUMMARY OF THE SEVERITY AND SEED TRANSMISSION OF POTATO WILT IN PRINCE COUNTY OVER A NINE-YEAR PREIOD

Variety—Irish Cobbler

Year	Fields rejected for wilt	Average percentage wilt	Average percentage wilt in the same stock of the preceding year
1930	8	5.7	0.27
1931	3	8.0	0.0
1932	1	2.0	0.0
1933	6	4.4	0.0
1934	11	11.5	0.85
1935	16	5.5	0.40
1936	6	2.8	0.45
1937	15	5.6	0.56
1938	20	7.3	0.46

It is apparent from these results that most fields rejected for wilt in recent years were grown from stock that exhibited field symptoms of this disease in the preceding year.

A test was conducted to determine whether stem-end sets from diseased stock were more liable to produce diseased plants than those from the eye-end. It was found in a test involving 128 plants of each that the eye-end sets produced 62.0% more wilted plants than those from the stem-end. It would seem from these results that the fungus permeated the tuber tissue before spring planting took place. Pethybridge (7) demonstrated that the wilt fungus was not localized in the stem-end of the potato because he obtained a high percentage of diseased plants from both eye and stem-end sets.

THE EFFECT OF WILT ON YIELD

A field test was conducted to study seed transmission of wilt and its effect on yield.

The following are the yields in bushels per acre from diseased and relatively healthy plots. Sets planted to rows 17, 18, 19, and 20 were from wilt stock of the previous year, while those planted to rows 21, 22, 23, and 24 were from certified stock. Planting was done on June 8 and 128 sets were planted to each row.

TABLE 5.—THE EFFECT OF VERTICILLIUM WILT UPON YIELD

(Variety—Irish Cobbler)

—	Row number	Yield in bushels per acre			Percentage wilt
		Marketable	Unmarketable	Total	
Wilt stock	17	294.9	86.1	381.0	—
	18	260.0	86.0	346.0	—
	19	242.9	97.4	340.3	—
	20	309.1	87.0	396.1	—
	Averages	276.7	89.1	365.9	39.6
Certified stock	21	376.2	40.7	416.9	—
	22	358.3	39.7	398.0	—
	23	349.7	42.5	392.3	—
	24	371.5	64.3	435.8	—
	Averages	363.9	46.8	410.8	2.3

The plot with approximately 40% of wilt showed a 24% reduction in yield of marketable tubers over that showing only a slight amount. Total yield was reduced by 11%.

A further test of the effect of wilt on yield was carried out by interspersing wilt sets among healthy sets in the rows in the ratio of three healthy sets to one diseased set. The test comprised four dates of planting with two rows of 128 sets to each planting with results as shown in Table 6.

TABLE 6.—THE EFFECT OF VERTICILLIUM WILT UPON YIELD

(Variety—Irish Cobbler)

—	Planting date	Row number	Yield in bushels per acre			Percentage wilt
			Marketable	Unmarketable	Total	
Plants next to healthy plantings	June 1	5 and 6	334.7	52.9	387.6	1.6
	8	7 and 8	332.7	64.3	397.0	0.0
	15	9 and 10	289.3	22.7	312.0	0.0
	22	11 and 12	236.3	37.8	274.1	0.0
	Average		298.3	44.4	342.7	0.4
Healthy plants next to diseased plantings	June 1	5 and 6	346.9	43.5	390.4	10.2
	8	7 and 8	342.2	50.1	392.3	4.7
	15	9 and 10	272.3	30.2	302.5	0.0
	22	11 and 12	260.9	36.9	297.8	0.0
	Average		305.6	40.2	345.8	3.7
Diseased plantings	June 1	5 and 6	221.2	51.1	272.3	73.4
	8	7 and 8	198.5	54.8	253.3	68.8
	15	9 and 10	202.3	37.8	240.1	40.6
	22	11 and 12	156.9	51.0	207.9	54.7
	Average		194.7	48.7	243.4	59.4

From the above results it would appear that infection taking place in the field has no immediate effect on reduction in yield, but when tubers from affected plants are used for seed considerable reduction in yield follows.

The plot with an approximate 60% wilt infection showed 35% reduction in yield of marketable tubers compared with yield from certified seed. Total yield was reduced approximately 30%.

The important feature to be noted from the foregoing results is the extent to which the yield of marketable tubers was reduced where high percentages of wilt were encountered. It is also thought that with the same percentages of wilt in a rather dry year, reduction in yield would have been much greater.

CONTROL

Control measures advocated as a result of investigations carried out at Charlottetown and on the findings of previous investigators are as follows: (1) Plant seed known to be free from the disease. (2) Rogue out diseased plants and those immediately adjacent. (3) Practise a long rotation where the disease has been encountered.

SUMMARY

A survey of the prevalence of wilt disease in Prince Edward Island has revealed this malady to be a problem of importance in Prince and Queens Counties during recent years.

The problem of successfully combating this disease, dependent on the seed potato inspection service, is rendered almost impossible because of difficulties entailed in estimating the presence and severity of this trouble in the field. Time of inspection and the appearance and development of wilt are variable factors. Environmental conditions may modify or aggravate symptom expression and such diseases as early and late blight may totally mask any wilt present.

Numerous isolation studies and subsequent pathogenicity trials have demonstrated that this disorder, locally referred to as "wilt disease", is due to the fungus *Verticillium albo-atrum* R & B.

Verticillium has been found to exhibit good growth on artificial media over a wide temperature range of 60 to 77° F. Maximum growth occurred from 66 to 77° F. or 19 to 21° C.

Major epidemics of wilt disease developing in the field have had their origin in diseased stock of the previous year. Tuber index trials have shown that wilt plants develop from both eye and stem-end sets of diseased tubers.

The chief economic effect of wilt is apparent in reduction in yields of marketable tubers.

The only effective control measures advocated at present consist in the use of disease-free seed and the disposal of wilted plants along with those immediately adjacent. It is considered advisable to practise a long rotation where wilt has been encountered.

ACKNOWLEDGMENT

The authors are greatly indebted to the Seed Potato Inspection Service in charge of Mr. S. G. Peppin for much valuable data regarding the prevalence of wilt in Prince Edward Island.

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GROWTH AND FEED CONSUMPTION OF BACON HOGS[1]

E. W. Crampton[2]

Macdonald College (McGill University), Quebec

[Received for publication July 24, 1939]

The most frequently used criterion of the nutritive value of typical rations for hogs is the gain in body weight of the animals subsisting thereon. Live weight gain is used also as an index of hereditary tendencies as to rate of maturity where pigs are fed identical rations. This latter is one of the items considered in the elegibility of sows for advanced registry under the policy at present in operation in Canada. In many investigations where growth rate is not the unit of measurement used in the evaluation of the imposed experimental condition, live weight gains over a given period or weight attained at a given age are nevertheless factors which must be considered in the interpretation of the results. Quite aside from any value in scientific studies, a normal growth curve for bacon hogs would frequently be useful as a standard by which the practical feeder could gauge the results of his particular hog management and feeding programme. To date no growth data for Canadian bacon hogs have been published from which a normal growth curve might be plotted.

That there is a real correlation between the live weight increases and the quantity of feed eaten by pigs over the corresponding period is accepted. The relation between the amount of gain and the amount of feed eaten, though real, is by no means constant. Rather, it changes both with the age of and with the weight attained by the pig. Published data are lacking for what may be called "normal" feed consumption of market pigs of bacon type. Without data for normal growth and for normal feed consumption, no clear picture of typical feed efficiency in terms of "feed to gain" ratios at any given age of pig is possible.

One of the products of the system of individual feeding which has been followed in the experimental swine herd at Macdonald College since 1928 is data relative to the live weight and the feed consumption of pigs. Certain of these data are suitable for the construction of typical growth and feed consumption curves. Such curves are herewith presented as Figures 1 and 2. The plotting data are found in Appendix Tables 1 and 2.

SOURCE AND NATURE OF DATA

In order that these curves may be properly interpreted, the source of the data and the statistical procedures used in obtaining the final plotting data are described in some detail.

At the outset it may be noted that the swine herd at Macdonald College has for a number of years been maintained as an experimental unit. The numbers of pigs raised in any one year has been largely determined by the numbers needed for the experimental studies planned. Thus practically all pigs weaned have been used in one or another feeding trial.

[1] Macdonald College Journal Series No. 130.
[2] Associate Professor of Animal Nutrition.

FIGURE 1. Live weights of Yorkshire pigs from birth to 28 weeks of age. Shaded area marks limits of $\pm$ one standard deviation about the mean.

These trials have involved a variety of rations, but the management of the pigs from which the data for the growth and feed consumption curves were taken has had the following features in common:

Pigs were all of Yorkshire breeding. Their dams were raised at Macdonald College and during any one year were usually half sisters through their sire. Litters were weaned at 60 $\pm$ 4 days of age and averaged 10 pigs weaned per litter.

About 80% of the pigs were fed slop feed made by mixing, at the time of feeding, the dry meal allowance with the water allowance. The other pigs were self fed their dry meal mixtures and had water *ad libitum.*

Pigs other than those self fed were from weaning time to a weight of 100–125 pounds fed thrice and thereafter twice daily. They were fed to the limit of appetite in all cases.

Pigs were marketed individually as they reached a weight of approximately 200 pounds. This practice has, for the ages beyond that at which the first pigs have reached market weight, reduced somewhat the average weights shown in the growth curve from what they would have been had these more rapidly growing pigs remained in the population. This factor becomes operative after the age of 22 weeks. Its effects are particularly noticeable in Fig. 3.

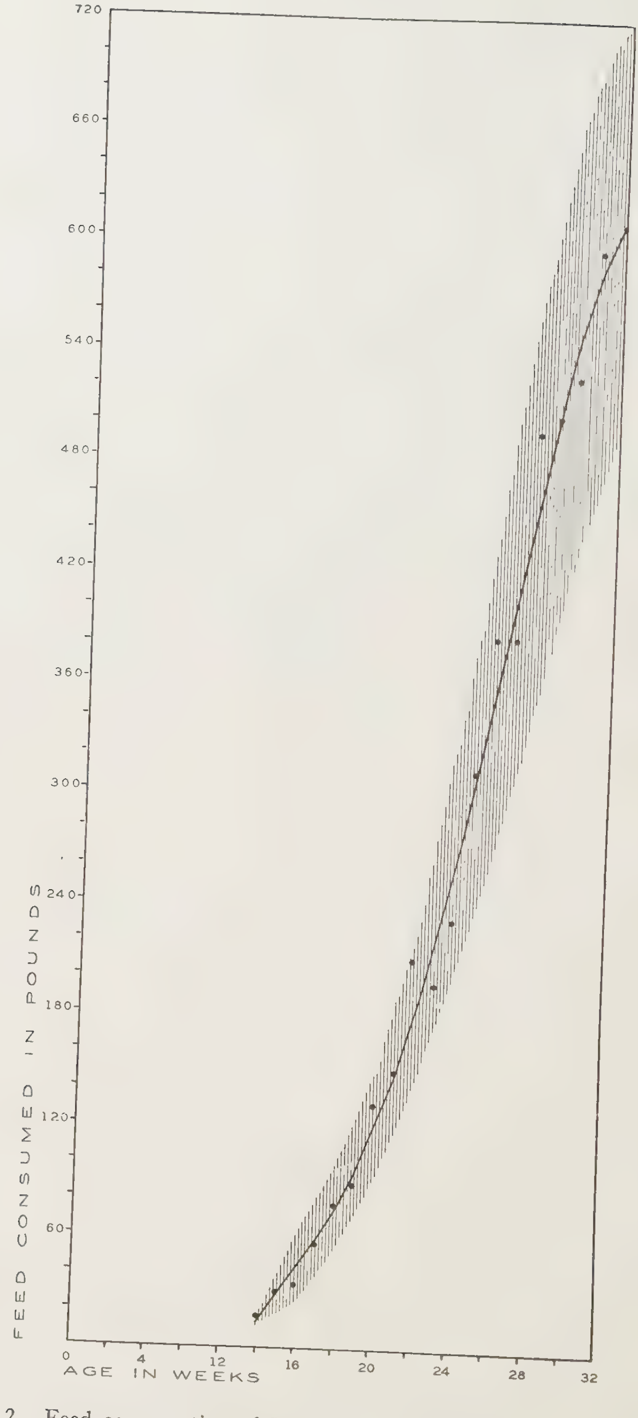

FIGURE 2. Feed consumption of Yorkshire pigs to 28 weeks of age. Shaded area marks limits of ± one standard deviation about the mean.

Live weights and feed consumption records were made at fixed intervals during a given experiment. Since not all pigs started on feeding trials at identical ages, the live weights and feed records are not uniformly distributed over the range of ages. The numbers of pigs contributing to the plotting data at each age period are shown in Appendix Tables 1 and 2. Records of birth weight have been available only during the past two years.

Rations

The rations involved can be best described by considering the basal and supplemental fractions separately. The basal fractions consisted of various combinations of barley, oats, corn and rice feed. The latter product constituted up to 25% of some of the rations. For most of the pigs the basal feed consisted of about equal parts of barley and oats.

The supplement was a mixture whose composition closely approximated tankage 50%, non-oily fishmeal 15%, linseed oilmeal 20%, bone char 10%, and salt 5%. Some variations in the proportions of these ingredients were made from one test to another and in some cases soyabean oilmeal was included as part replacement of linseed oilmeal, and limestone for bone char.

The rations fed to the pigs from weaning to 100–125 pounds were a combination of 15% of the mixed protein-mineral supplement plus 85% of the basal feed mixture. From 100–125 pounds to market weight the rations were changed to reduce the proportion of supplement to 10%. These meal mixtures contained all food given the pigs excepting that the animals under 100 pounds received about a teaspoonful of cod liver oil daily. No milk, green feed or other such material was fed at any time and the pigs were housed indoors in individual pens from weaning time until shipped to market.

The variations in ration formulae have not resulted in marked difference in the calculated digestible protein nor total digestible nutrient contents of the several mixtures in so far as these are indicated by figures from Morrison (2). A statistical analysis of the rations fed to pigs from weaning to 100–125 pounds weight showed the following averages and standard deviations:

Number of different ration mixtures	35
Average digestible crude protein	14.6% ± 1.3%
Average total digestible nutrients	75.3% ± 2.3%

Finishing rations averaged approximately 13% calculated digestible crude protein and were in general less variable in composition than the growing rations.

Preparation of the Growth and Feed Consumption Curves

The first step in the statistical treatment of the original data was the distribution of the individual weight and feed consumption figures into their proper weekly age groups. Thus, for example, all live weight and feed records of pigs between the ages of 27 and 84 days were brought together. For each weekly age group the mean weight and the standard deviation was calculated. The mean weekly live weights were then plotted against

age and a 4th degree curve fitted by Fisher's Summation Method of Fitting Polynomials (1). Similarly the data for the air dry feed consumed to each week of age were reduced to a fitted curve of feed consumption. These curves appear as Figures 1 and 2.

In order to indicate the variation from the average values, these curves are bounded by a shaded area equal in width at each weekly point to the standard deviation of the original values found for that age group. Between the minimum and maximum values included in $\pm$ one standard deviation one will expect to find approximately two-thirds of the individual pig weights (or feed consumption values). Also one would expect about one-sixth of the originally observed weights to be greater than the mean plus one standard deviation, and one-sixth less than the mean minus one standard deviation. For example, reading from Figure 1, 16-weeks old pigs should average 74 pounds in live weight. Out of 100 such pigs about 67 of them may be expected to weigh between 61 and 87 pounds. There will probably be 16 or 17 that weigh more than 87 pounds and there are likely to be an equal number of poorer doing ones that are as yet below 61 pounds.

Turning to Figure 1 we see that 16-weeks old pigs which have been full fed have on the average eaten 118 pounds of feed (air dry weight). Two-thirds of them will have eaten between 90 and 145 pounds. One-sixth of the best feeders may have eaten more than 145 pounds each while the slowest feeders may not yet have consumed 90 pounds of feed.

It is this variation in feeding ability which largely explains the variations in live weight attained at any given age. The reason for the variation in feed intake may of course depend on many factors. It should be borne in mind, however, that in so far as these data are concerned, crowding at the feed trough is not involved for each pig was housed and fed individually and was allowed daily all the feed he would consume. Type of ration and hereditary tendencies of course have presumably been causal factors.

RATE OF GAIN, AVERAGE DAILY FEED, AND RATION EFFICIENCY

From the data on weight for age and for feed consumption may be calculated: (1) the average rate of gain per day of pigs of varying ages; (2) the average daily feed intake; and (3) the quantity of feed eaten for each pound of gain in weight made. These calculations have been plotted in Fig. 3.

The calculations involving feed are not shown for pigs earlier than the 11th week. Most of the pigs have started on feeding tests at about 70 days of age. With particularly growthy pigs a few will have started earlier. Such pigs, being larger for their age, will show a higher daily feed intake than average. Hence below the age of 11 weeks as in the case of pigs above 22 weeks the group is not strictly normal in that at the youngest ages (*i.e.*, below 11 weeks) feed records are available only for the growthiest pigs, while for the ages beyond 22 weeks, the fastest growing, and best feeding pigs have been shipped to market. One might perhaps consider the curves "normal" between the ages of 11 and 22 weeks.

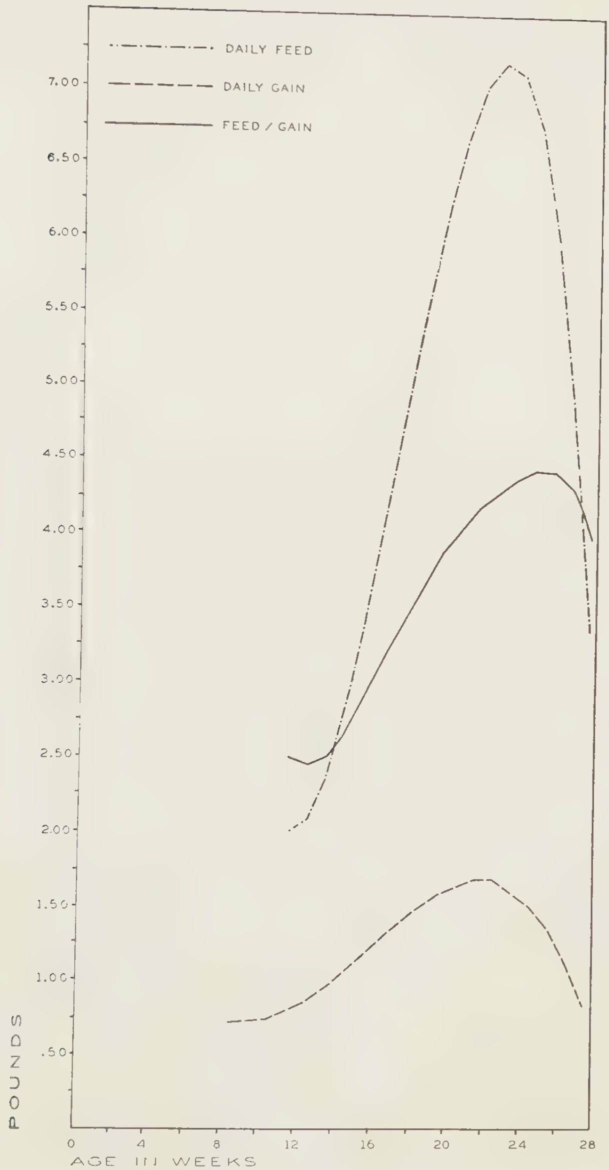

FIGURE 3. Average daily gains, daily feed, and "feed to gain" ratios of Yorkshire pigs according to age.

Rate of Gain

The average rate of gain of pigs, once they have really gotten started on man-made rations, increases weekly. For the first two weeks following weaning (weaning at 8 weeks) the gain is just under three-quarters of a pound per day. By the 15th week they are gaining one pound, and at four months nearly 1.25 pounds per day. Five-months old pigs should be gaining more than 1.5 pounds per day.

It will be noted that after 22 weeks the *average* rate of gain drops sharply. This is not normal, but is the result of the fact that at this age the best pigs have now reached market weight and have been shipped. Those pigs remaining are the slower gaining pigs. It takes but one look at this curve to confirm one's impression that once the best pigs have gone to market those remaining usually appear to be abnormally slow in finishing.

Average Daily Feed Consumption

One of the striking things brought out in these data is the rapid rate at which the daily feed intake increases up to the 22nd week. At the peak of the rate of gain the *average* daily feed intake is 7.2 pounds per day. With the removal of the best feeders from this age (22 weeks) onwards, the average feed intake drops rapidly, as does the daily gain. The relation between poor feeders and slow rate of gain is strikingly shown in these two curves.

Feed Eaten per Unit of Live Weight Gain

The "feed to gain" ratio has been extensively used as a criterion of the nutritive value of a ration. When used in a comparative sense as between results of comparable feeding groups it is a useful term. Frequently one sees in the popular literature this term without qualification as to age of pig. When thus employed, values given may be misleading. The extent of the change of the feed to gain ratio with age is evident from the curve in Figure 3. Whereas pigs of three months of age increase one pound in weight with 2.5 pounds of feed eaten, average pigs of 22 weeks will require about 4.2 pounds for the same gain in live weight.

The decreasing efficiency of the ration with increasing age up to the time of marketing the best pigs is merely the expression of the gradual change in the use to which the feed is being put by the animal. In the early ages tissue increase is of low energy value as compared to that laid down during the "fattening" period. Coupled with this must be recognized a continually increasing maintenance requirement resulting from the ever-increasing body size. Thus the ration, with a relatively constant energy value, must be eaten in increasing amounts to result in a unit of gain.

Studies now in progress at this Station indicate that not less than two-thirds of the feed intake is used for body maintenance by normal market pigs of any age. If this is true, there is little justification for limited feeding as a method of economizing in the feed cost of gains. Certainly the younger the pig the greater the economic reason for full feeding. Extensive data from this Station fail to indicate any damaging of carcass excellence by full feeding.

The drop in the feed to gain ratio curve at the older ages is a reflection of the fact that these older, slower doing pigs are not fattening rapidly, and are using a relatively larger fraction of their feed for low energy tissue growth. This should not be interpreted as an argument for curtailing feed consumption with an idea of greater economy in production. Poor feeders are seldom profitable. While the data for 28 weeks old pigs show gains at smaller feed cost than is the case with 20-weeks old animals, these pigs are not fattening. Rather they are maturing. Such pigs at 200 pounds will not be finished and their carcasses will be penalized when

graded by Canadian bacon standards. Furthermore it will be noted that the 28-weeks old pigs are gaining only 0.85 pound daily and eating 3.4 pounds of feed, or a requirement of 4 pounds feed for each pound of gain made. Pigs 16-weeks old will normally eat 3.4 pounds feed daily but will gain 1.16 pounds per day or a gain of 1 pound on each 2.96 pounds of feed eaten.

SUMMARY

Curves are presented of growth and average feed consumption of Canadian Yorkshire pigs being raised for bacon production.

The variation about the mean weights and mean feed consumption, through the range of ages covered, is indicated in Figures 1 and 2 respectively by shaded areas marking one standard deviation above and below the means. Thus about two-thirds of the observed values lie within this range, with one-sixth above the higher and one-sixth below the lower values.

The data are taken from the experimental swine herd at Macdonald College from pigs which, from weaning time to market weight, were individually penned and fed indoors and fed to the limit of appetite. The rations in general consisted of 85% to 90% of basal feed mixtures, (made up of varying combinations of cereal grains), plus 10% to 15% of mixed protein-mineral supplements in which tankage, fishmeal, linseed oilmeal, bone meal and salt were the chief constituents. Pigs were marketed as they reached 200 pounds live weight. Thus from the ages of 22 weeks onward the population consisted of increasing proportions of slower growing pigs. The effect of this change in population is especially apparent in the curves of daily gain, daily feed intake and the feed to gain ratios. The growth and feed consumption curves might be considered "normal" between the ages of 11 and 22 weeks of age.

Appendix Table 1.—Average live weight of market pigs from birth to 28 weeks of age

Age of pig (weeks)	Number of observations	Average weight (lbs.)	Standard deviation (lbs.)	Coefficient of variation (%)	Polynomial values for Figure 1
Birth	154	2.7	0.4	15	
8	127	26	6	22	25.4
9	173	31	7	22	30.8
10	191	36	6	17	35.9
11	151	39	8	21	41.0
12	64	45	9	21	46.5
13	128	53	12	23	52.4
14	142	60	11	18	59.0
15	71	64	18	28	66.4
16	85	79	19	25	74.5
17	124	85	20	24	83.5
18	97	102	15	15	93.3
19	50	99	14	14	103.8
20	61	105	18	17	114.9
21	77	123	28	23	126.4
22	220	144	29	20	138.1
23	149	144	35	24	149.8
24	80	174	34	19	161.1
25	125	172	31	18	171.7
26	136	175	31	18	181.2
27	79	192	30	15	189.2
28	64	194	20	10	195.2

Appendix Table 2. Average air dry feed eaten per pig to 28 weeks of age

Age of pig (weeks)	Number of observations	Recorded feed consumption on dry weight (lbs.)	Standard deviation (lbs.)	Coefficient of variation (%)	Polynomial values for Figure 2
10	4	17	6	34	13.6
11	28	30	5	18	28.9
12	46	34	8	25	42.9
13	110	56	29	52	57.5
14	137	76	20	26	74.1
15	68	88	32	36	94.0
16	82	131	44	34	118.0
17	126	150	55	36	146.8
18	96	209	48	23	180.4
19	52	196	41	21	218.9
20	58	230	48	21	261.9
21	75	310	94	30	308.4
22	218	383	81	21	357.6
23	146	383	101	26	407.9
24	81	494	127	26	457.6
25	118	502	94	19	504.8
26	128	523	116	22	546.9
27	69	591	108	18	581.4
28	60	604	93	15	605.1

Appendix Table 3.—Average daily gain, daily feed and feed to gain ratios of market pigs according to age

Age of pig (weeks)	Average daily gain (lbs.)	Average daily feed (lbs.)	Feed/gain ratio	Age of pig (weeks)	Average daily gain (lbs.)	Average daily feed (lbs.)	Feed/gain ratio
9	.76			19	1.50	5.50	3.67
10	.73			20	1.58	6.13	3.88
11	.74	2.19	2.96	21	1.64	6.65	4.05
12	.80	2.00	2.50	22	1.67	7.02	4.20
13	.85	2.08	2.45	23	1.67	7.19	4.31
14	.94	2.37	2.52	24	1.62	7.11	4.39
15	1.05	2.84	2.70	25	1.52	6.73	4.43
16	1.16	3.43	2.96	26	1.36	6.02	4.43
17	1.28	4.11	3.21	27	1.14	4.92	4.32
18	1.40	4.81	3.44	28	.85	3.39	3.99

REFERENCES

1. Fisher, R. A. Statistical methods for research workers, Chapter V, Oliver and Boyd, London. 1936.

2. Morrison, F. B. Feeds and feeding. Morrison Publishing Co., Ithaca, N.Y. 1936.

BOOK REVIEWS.

ANLEITUNG ZUM QUANTITATIVEN AGRIKULTURCHEMISCHEN PRAKTIKUM (Laboratory Manual for Quantitative Agricultural Chemistry) by George Wiegner; Second revised edition by H. Pallmann. 389 pages. 1938. Verlag Gebruder Borntraeger, Berlin.

This laboratory manual for quantitative agricultural chemistry is designed as a text for a college laboratory course. As it comprises analyses of fertilizers, soils, feed, dairy products and wine, it cannot include numerous methods for each type of determination. The methods are explained very clearly. The reactions involved are shown, amounts of the material to be analyzed and of the chemicals used are given in detail and the necessary calculations are indicated. Frequently a paragraph containing evaluation of the results is attached. A chapter introducing the student to the principles of quantitative chemistry precedes the specific analyses of agricultural materials.

Due to its thoroughness this book seems eminently well suited for college use and it is also valuable as a reference for the advanced worker.

The largest part of the volume is devoted to soil analyses. Conforming with the title most of these are of chemical nature, while one chapter is devoted to mechanical analyses. The book would have gained considerably as a text for soil students if a number of other physical analyses of soils had been included. Most of the important phases of quantitative chemical soil analyses are represented. However, such items as the following are not mentioned or are insufficiently stressed:

Quick tests of soils and plants for the determination of available plant nutrients in soils;

The study of soil colloids; silica-sesquioxide ration, base exchange phenomena, flocculation and aggregation.

This reviewer is not qualified to judge the value of the chapters on feed, dairy products and wine. They appear to be prepared in the same thorough and well-organized style as the parts on soils and fertilizers.

DR. H. KOHNKA.

Soil Conservation Service,
Lafayette, Indiana.

ROACH, W. A. Plant injection for diagnostic and curative purposes. (Foreword by Prof. V. H. Blackman, Sc.D., F.R.S.). Technical Communication 10 of the Imperial Bureau of Horticulture and Plantation Crops, East Malling, Kent, England, 1938, pp. 78, plates 2, text figures 47, bibl. 162, 5/–.

Man has toyed for centuries with the idea of feeding his fruit trees direct instead of by more orthodox but slower methods and in the heyday of the Italian Renaissance we find Leonardo da Vinci noting that if it is desired to produce poisoned fruit the injection of fruit trees offers a way.

More recently various "tree doctors" have suggested that easy rejuvenation of orchards can be effected by the use of their own particular injection methods, but such methods have always been somewhat suspect, since obviously different conditions demand different remedies and the cure may prove worse than the disease.

It has remained for Dr. Roach to bring order out of chaos and show those of us who are attracted by the idea how to set about our investigations.

He starts by giving a history of injection work in Europe and the U.S.A., paying particular attention to that published in recent years on the detection and cure of deficiency diseases. He notes also the successful use of injection for purely physiological purposes, as, for instance, of glucose into vines, just before bud break to ensure a good fruit set. He points out, moreover, how injection methods may be of great value in the study, not only of mineral deficiencies, but also of rootstock influence and of the effect of the chemical constituents of a fruit on its storage capacity.

Recent cases of successful injection cited include the following:—diagnosis of incipient chlorosis of the iron shortage type at East Malling; diagnosis and cure of a copper deficiency dieback disease in apples in Western Australia; determination of the cause and cure of boron deficiency diseases of apples in Canada and New Zealand; increase in vigour and freedom from insect pests in apple trees injected with solutions of various chemical solutions in England.

His own experiments have been in progress for seven years on material which has ranged from the strawberry plant to fully grown apple and plum trees, and most of the present paper is devoted to a consideration of the methods used. It is for this clear and illustrated account that horticulturists will be particularly grateful. He describes in detail with the help of text figures and lists of tools the technique used for the injection of particular parts of standing trees and other plants, varying in size from a single interveinal area of a leaf to whole main branches, noting, moreover, the type of problem for which each particular method is best suited. He shows how in the most delicate methods the injection of leaves and their comparison with neighbouring untreated leaves or parts of leaves enables a rapid diagnosis to be made of the mineral deficiency from which a plant or tree is suffering. He describes how whole trees may be injected for experimental purposes or even for economic reasons in the commercial orchard.

In short he shows us how to carry out the operations advocated and how to avoid those many pitfalls which await the over-zealous, although he is far from suggesting that all his methods are perfect.

He invites criticism and the experience of others in the same field.

Charley, V. L. S. and Harrison, T. H. J. Fruit juices and related products. Technical Communication 11 of the Imperial Bureau of Horticulture and Plantation Crops, East Malling, Kent, England, 1939, pp. 104, figures 49, bibl. 118, 5/–.

Whether we have suddenly developed sense, or whether the old slogan "an apple a day keeps the doctor away" has at last struck home, is immaterial. The fact remains that we do eat more fruit and that more fruit

is being produced. Market quality standards have become higher and growers are now faced with the problem of how to dispose satisfactorily of fruit which does not come up to the accepted standards of size or colour, though otherwise perfectly good. Among processes offering a solution, that of unfermented juice production has long commended itself to fruit producers in Europe and the U.S.A.

Hitherto, though short articles on different aspects of processing have been available since 1914 in the annual reports of the Long Ashton Research Station, lack of precise information on the exact technique employed has checked progress in England.

It has remained for Charley to give under one cover a complete detailed account of the manufacture of apple juice based on his knowledge of the latest foreign methods and on his own continued investigations at Long Ashton.

In the present bulletin he deals with the manufacturing process in detail starting with the selection of the fruit and taking us through every stage in turn up to the disposal of the final product in bottle, can or other type of dispenser. He does not confine his remarks to any one process but gives particulars of different methods found satisfactory and discusses their merits.

Further he deals more briefly with such other fruit products as grape, citrus and soft fruit juices, cider, fruit wines, etc., with the concentration of fruit juices by hot processing, by freezing and by spray drying, and with the disposal of pomace.

He describes methods of analysing juice for the determination of specific gravity, total acidity, tannin, alcohol and sulphur dioxide.

Finally he discusses the suitability of particular metals and alloys for the construction of the requisite apparatus, the clear illustrations of which add greatly to the usefulness of the publication.

But the problems of juice production do not, unfortunately, begin and end with its manufacture, and the economic and nutritional aspects are equally important. We are, therefore, grateful to Harrison for his concise and adequate treatment of them in the first twenty pages.

He shows that a permanent fruit juice industry on a large scale can only be developed where large supplies of raw material are available each year at a reasonable price. The cost of manufacture is not small, and if sales are to grow it is essential that retail prices should be reasonably low so as to compete with other drinks. This means that distribution costs must be low and that the industry must depend essentially on its home market. Here regulations are necessary to protect it from competition with synthetic products.

The nutritive and therapeutic qualities of fruit juices are discussed at sufficient length to show their great value, not only to children and invalids and for the treatment of gastric troubles, but also in the diet of the normal healthy adult.

A short glossary is included for the use of the less expert, and this together with the comprehensive index should make the information readily accessible to all.

Garner, R. J. and Walker, W. F. The frameworking of fruit trees. Occasional Paper Imperial Bureau of Horticulture and Plantation Crops, 5, 1938, pp. 19, bibl. 26, 1s.

The authors set out briefly, but intelligibly, the results of practical orchard experiments in Tasmania, England and elsewhere, on methods of topworking and thereby changing the variety of fruit trees at will.

The method commonly accepted in the past has consisted—to put it somewhat crudely—in chopping off the top of the tree and inserting one or two grafts into the stump, or into not more than the two or three branches which remain.

The method which they describe consists essentially in the insertion of a very large number of grafts right out at the ends of all the smallest branches. The labour involved is very much greater but the return of the tree to productivity is also greatly accelerated and would appear to make the practice worth while.

Four ways of carrying out the operation are described, namely, stub-grafting, side-grafting, inverted L bark-grafting and awl-grafting. Clear line drawings greatly facilitate an understanding of the methods, while photographs showing an apple tree immediately after treatment and another similar tree two years after treatment bearing five bushels of fruit, demonstrate the results which can be expected.

Possible difficulties, choice of grafting wax, costs and other practical points are all fully discussed.

AUTHOR INDEX

ERRATA

See pages 240 and 686.